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HUMAN RESOURCES, LOGISTICS AND COST FACTORS IN WEAPON SYSTEM DEVELOPMENT: DEMONSTRATION IN THE FULL SCALE DEVELOPMENT PHASE OF AIRCRAFT SYSTEM ACQUISITION

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This technical report has been reviewed and is approved for publication.

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Commander

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This report documents the final part of a three-part demonstration of the coordinated human resources technology (CHRT) on an aircraft acquisition program. CHRT is an integration of five human resource technologies: maintenance manpower modeling; human resource in design trade-offs; instructional system development; job guide development; and system ownership costing. The CHRT methodology also includes a consolidated data base (CDB) which services the five integrated technologies. CHRT was conceived and developed (a) to assess the impact of system design and support plans on human resource, logistics, and cost throughout acquisition, and (b) to facilitate the implementation of an integrated personnel, training, and technical manual support approach. In this part of the demonstration, CHRT and the CDB were applied to the avionics and landing gear systems of the Advanced Medium

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STOL[1] Transport (AMST) using data projected for the minimum engineering development phase. This phase may be considered similar to full-scale development but lesser in scope. The following results were achieved. First, manpower requirements, training requirements, technical manual requirements, reliability, maintainability, and system ownership costs were assessed and quantified for several avionics and landing gear design and support alternatives at various levels of system detail. Second, a sample integrated training program and technical manual were prepared for a selected landing gear maintenance task. Third, the consolidated data base was continued and expanded for both the avionics and landing gear systems.

[1]STOL - Short takeoff and landing

SUMMARY

Problem and Objective

The Air Force Human Resources Laboratory (AFHRL) initiated a two-phase effort to integrate five human resource technologies as the coordinated human resource technology (CHRT) and apply it to the weapon system acquisition process. The five technologies are human resources in design trade-offs, maintenance manpower modeling, instructional system development (training), job guide development (technical manuals), and system ownership costing. The CHRT methodology also includes a consolidated data base (CDS) to provide data for the five integrated technologies. Phase One, the integration of these technologies, and the development of the concept of the CHRT and the CDB is documented in AFHRL-TR-78-6, Volumes I, II, and III (references 2, 3, and 4).

Phase Two, the application of CHRT in a weapon system acquisition program was demonstrated in three parts: Part 1 used Advanced Medium STOL[1] Transport (AMST) conceptual phase data; Part 2 used AMST validation (prototype) phase data; and Part 3 used projected AMST full-scale development (minimum engineering development) phase data. The results of Parts 1, and 2 of the demonstration are documented in AFHRL-TR-79-28, Volumes I and II (references 9 and 10). The objective of the present report is to document the results of Part 3.

Approach

The AMST minimum engineering development (MED) phase, which was to provide source data for Part 3 of the demonstration, was delayed at the time that work on Part 3 was about to begin. Consequently, the MED phase source data had to be projected. The projection was based on the C-141 landing gear and Government furnished avionics equipment, both similar to the hardware that was expected for the AMST.

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1 STOL - short takeoff and landing.

The projected data for the landing gear and avionics equipment were determined. Alternative designs and alternative support plans for the landing gear and avionics systems were identified. The CHRT methodology and the CDB were applied to provide an analysis of these design and support alternatives, and to provide an integrated personnel, training, and technical manual program for the landing gear system. During the course of the demonstration, the CHRT techniques and the data products were evaluated. The techniques were improved, added to, or deleted where necessary. Data product presentations were improved. In all cases, CHRT was applied as it might be by a system program or acquisition logistics manager.

Results and Conclusions

The overall objective of this part of the demonstration was to determine the feasibility of applying the CHRT methodology and the associated consolidated data base (CDB) to the full-scale development phase of acquisition. This was accomplished and the following results were achieved.

A. Manpower requirements, training requirements, technical manual requirements, reliability, maintainability and system ownership costs were quantified for several design alternatives at various levels of detail. These included:

1. A two-member flight deck avioncs suite
2. A modified landing gear system
3. Discrete VHF/AM and VHF/FM ratios
4. Combined VHF/AM/FM radios
5. Standard station-keeping equipment
6. Modified station-keeping equipment
7. Steel brakes
8. Carbon brakes
9. Assembly programming language

10. Higher order programming language

B. The technique to assess logistics support alternatives which was developed in the previous parts of the demonstration was expanded and demonstrated further. In this part of the demonstration, the technique was used to evaluate two support concepts, "conventional" and "task- oriented"; and two types of maintenance, "scheduled" and "unscheduled." The "conventional" concept assumes primarily 5-skill-level personnel on the flightline, supported by conventional training and standard technical manuals. This concept was assessed for all the designs listed above. The "task-oriented" concept assumes primarily 3-skill level personnel on the flightline, supported by task-oriented training and proceduralized technical manuals. This was assessed for the flight deck avionics suite and the modified landing gear. The two types of maintenance were assessed for both station-keeping equipment alternatives.

C. An integrated approach to personnel, training, and technical manual development was continued also in this part of the demonstration.

1. A training/aiding matrix was prepared as it might be in early full-scale development. The matrix provides information needed to re-evaluate the requirements for special training and technical manual requirements identified in previous phases.

2. A task analysis of landing gear maintenance was conducted on the C-141 landing gear, and the intermediate products required for development of a coordinated training program and technical manual set were prepared. The task analysis and intermediate products were limited to the brake removal and replacement task. Sample intermediate products are provided in this report.

3. A coordinated training plan and technical manual sample set were prepared for the brake removal and replacement task using the intermediate products as a source. A description of the technique used, and the training and technical manual products prepared, are included in this report.

D. The CDB that serves the integrated data requirements of the five technologies as implemented by CHRT was maintained for both the avionics and landing gear

systems. The CDB was maintained in both computer and hard copy form. This data base evolved from the data base established in the conceptual phase demonstration and subsequently updated in the validation (prototype) phase demonstration. The data base was again updated and maintained in this part of the demonstration to support the full-scale development phase requirements.

PREFACE

This study was performed by Dynamics Research Corporation (DRC), 60 Concord Street, Wilmington, Massachusetts. Technical direction was provided by the Logistics and Technical Training Division, Air Force Human Resources Laboratory (AFHRL) Wright-Patterson Air Force Base, Ohio.

The AFHRL support was provided under project 1959, Advanced Systems for Human Resources Support of Weapon Systems Development, and work unit 1959-00-02, Integration and Application of Human Resource Technologies in Weapon System Design. Lieutenant Colonel John Adams was the Project Director. Dr. William B. Askren was the Work Unit Scientist.

The Advanced Systems Department staff at Dynamics Research Corporation performed the research under contract F33615-77-C-0016 with Mr. Gerard F. King as Principal Investigator.

Many individuals throughout the Department of Defense and industry contributed their ideas and opinions to this effort. Of special note, however, were the members of the AFHRL Logistics and Technical Training Division who contributed both their specific areas of expertise and in the total development of CHRT. These individuals and their areas of expertise are Robert N. Deem, maintenance manpower modeling; Dr. Donald L. Thomas, job guide development and instructional system development; Harry A. Baran, system ownership costing; and Dr. Lawrence E. Reed, consolidated data base. Lieutenant Colonel Dalton Wurtanen and Major Robert Pucik of the AMST Program Office provided the interface with the AMST acquisition effort. Appreciation is also extended to Dr. John P. Foley, Jr., for sharing his view of job guide development and the instructional system/job guide relationship.

Dr. Paul G. Ronco and Dr. John A. Hansen of Man-Tech Incorporated, a DRC subcontractor, provided significant contributions in the development, demonstration and implementation of the integrated personnel, training, and technical manual approach. Specifically, they prepared the major portion of the intermediate training and technical manual products, performed the on-equipment task analysis, and drafted the sample training plan and technical manual.

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I. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The Logistics and Technical Training Division of the Air Force Human Resources Laboratory initiated a two-phase effort in 1977 to integrate and apply five human resource technologies as the coordinated human resource technology (CHRT) to the weapon system acquisition process. Phase I, the integration of these technologies and the development of the CHRT concept was completed in October 1977. Phase II, the demonstration of CHRT in a weapon system acquisition program was performed in three parts: Phase I, using conceptual phase data; Part 2, using validation phase data; and Part 3, using full-scale development phase data. The results of Part 3 are described in this report.

1.2 PHASE I - INTEGRATION OF FIVE TECHNOLOGIES

The Air Force Human Resources Laboratory has developed or has contributed to the development of five technologies which have a similar objective; namely, the improvement of personnel performance and manpower utilization in maintenance, support, and operations as well as the reduction of weapon system ownership costs. These technologies are: maintenance manpower modeling (MMM), job guide development (JGD), instructional system development (ISD), system ownership costing (SOC), and human resources in design trade-offs (HRDT). In Phase I, the development phase, the technologies were integrated and a methodology for application was developed. This methodology was called the Coordinated Human Resource Technology and was documented in AFHRL-TR-78-6, Volumes I and II (references 2 and 3). Phase I also results in the description of a Consolidated Data Base (CDB) which would service CHRT and eliminate the need for five separate data bases to service each technology. The CDB was described in AFHRL-TR-78-6, Volume

III (reference 4). Since the five technologies were merged into the CHRT methodology, they lose much of their individual identity in subsequent sections of this report.

1.3 PHASE II - DEMONSTRATION

During Phase II, the demonstration phase, CHRT and the CDB were applied on a weapon system acquistion program. The demonstration phase consisted of three parts: Part 1, using conceptual phase data; Part 2, using validation phase data; and Part 3, using full-scale development phase data. The phases took 3, 6, and 9 months, respectively. The Advanced Medium STOL[2] Transport (AMST) was the acquisition program selected for CHRT application. The actual conceptual and validation (prototype) phases of the AMST acquistion were complete and data appropriate to each phase were available when this demonstration began.

The original plan was to demonstrate CHRT during the actual AMST full-scale development (minimum engineering development) (MED) phase after some confidence and facility with the methodology had been developed during the conceptual and validation (prototype) phases. Unfortunately, the AMST program was indefinitely delayed before source selection was complete for the minimum engineering development phase. As a result, minimum engineering development phase data were considered source selection sensitive and could not be released.

In order to proceed with the CHRT demonstration, full- scale development (MED) phase data had to be projected. Off-the-shelf avionics that were Air Force candidates for inclusion on the AMST and the C-141 landing gear which was technically similar to that on the AMST were used as the projected data sources. A conscientious effort was made to limit data detail to only that which one could reasonably expect to be available during the projected phase.

For each phase of the demonstration, the appropriate data were compiled, baseline and alternative system designs and support plans were identified, and CHRT was applied. During the course of the demonstration, CHRT and its data products

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2 Short takeoff and landing.

were evaluated. The techniques used within CHRT were improved, added to, or deleted where necessary. Data products and presentation format were also improved to facilitate use of the CHRT information by the manager, decision maker, and training/technical data specialist. In all cases, CHRT was applied as it might be within a system program or acquisition logistics office. The results of Parts 1 (conceptual phase) and 2 (validation phase) of the demonstration are documented in AFHRL-TR-79-28, Volumes I and II (reference 9 and 10). This report, which also consists of two volumes, documents the results of Part 3 (full-scale development phase) of the demonstration. Volume I provides narrative and sample results. Volume II (Appendixes B to S) provides more extensive and detailed results.

II. DEMONSTRATION IN THE FULL-SCALE DEVELOPMENT PHASE

2.1 OVERVIEW

The demonstration of CHRT, in the full-scale development phase was conducted between 16 August 1978 and 15 May 1979. The AMST minimum engineering development (MED) phase was to be the CHRT demonstration vehicle. As such, it would have provided both a real-time source of data and an opportunity for a practical application of CHRT. The AMST program, however, was delayed during source selection and all data were secured as procurement sensitive. Appropriate AMST data, therefore, were simulated with projected data based on actual hardware from the C-141 landing gear and Government furnished avionics.

The system baselines assessed were the two-member flight deck (2MFD) avionics suite and a C-141 type landing gear, both supported with conventional training and technical manuals. The system level alternatives considered were the 2MFD avionics suite and a C-141 type landing gear, both supported with task-oriented training and technical manuals. During this phase of the demonstration, however, emphasis was placed on alternatives at the subsystem and line replaceable unit (LRU) levels. Those considered were as follows:

1. Discrete versus combined VHF/AM[3] and FM[4] radios

2. Standard versus modified station keeping equipment (SKE)

3. Carbon versus steel brakes

4. Higher order programming language (HOL) versus assembly language.

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[3] Very high frequency/amplitude modulation.

[4] Frequency modulation.

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Heavy emphasis was placed also on demonstrating a procedure for developing a coordinated training and technical manual product set. The purpose of these products would be to implement in the field, the integrated personnel, training, and technical manual approach reflected in the assessments. In order to limit this effort to manageable proportions, a specific task on the C-141 landing gear was selected as an example. This task was the removal and replacement of the main gear brake assembly. A task analysis was performed on actual equipment at Charleston AFB and intermediate products similar to those described in AFHRL-TR-73-43(1) (reference 7) were developed. These intermediate products were then used to prepare a sample training plan and technical manual for the task. Products were prepared to support the aircraft maintenance career field, Air Force specialty code (AFSC) 431X2 and the task-oriented approach to training and technical manuals.

Significant effort was expended also in the development of maintenance action networks for the landing gear support equipment (SE) and in the meshing of these with the landing gear maintenance action networks. The goal, the determination of SE requirements through application of both the reliability and maintainability (R&M) model and the logistics composite model (LCOM), was achieved. This was the first time that a LOCM simulation was run on a complete SE group and also the first time that an LCOM system simulation was used as the demand for an LCOM SE simulation.

The compatability between the R&M model and LCOM was improved also during this part of the demonstration. Automated and manual procedures for operating the R&M model with LCOM extended form 11 data were developed. Additionally, the possibility of operating the reliability, maintainability, cost model (RMCM) with LCOM output was investigated and found to be feasible.

2.2 THE AMST MED PHASE AND DATA SOURCES

The AMST MED phase was planned as a modified full-scale development effort. Upon completion, production would be initiated. The two prototype phase contractors submitted proposals to complete three basic tasks: (a) to modify one prototype for extended flight testing, (b) to perform avionics and cargo evaluations on the second basic prototype, and (c) to assess logistics requirements, critical hardware risks, and life cycle costs for the

proposed AMST. During the course of source selection, however, funding was reduced and the program was delayed. Technically, the AMST is still in source selection, and all proposal data are secured with the exception of the Air Force request for proposal (RFP) package.

To circumvent this lack of source data, the information in the RFP was supplemented with actual hardware data for off-the-shelf Government furnished avionics equipment and C-141 landing gear. These supplemental data were used to project data for the AMST. All prior CHRT data were updated to reflect this new information, and increased level of detail. Studies accomplished by the Aeronautical Systems Division (Deputy for Aeronautical Equipment), the Air Force Avionics Laboratory, and the Air Force Flight Dynamics Laboratory were used also to project AMST avionics data. These studies were used previously in the validation phase and were now re-examined for more detail. The landing gear information previously obtained from USAF Logistics Support Cost File Maintenance Register 66-1/IROS, KO51.PN8L was reviewed for currency and updated. Detail level data appropriate to the full- scale development phase were then extracted from these sources. Field visits also were made to several agencies and contractors to identify realistic alternatives and to obtain detail design data for these alternatives.

Additionally, a field visit was made to Charleston AFB to perform an integrated task analysis of selected landing gear maintenance activities. The task analysis was video taped for recoverability of information, and was used to develop both the intermediate and the final training and technical manual products.

2.3 CHRT RESULTS - FULL-SCALE DEVELOPMENT

The results of the CHRT demonstration are presented and discussed under a series of topics which relate directly to the factors that are considered or assessed in the CHRT process.

1. Baseline and alternative designs selected for assessment.

2. Reliability, maintainability, and maintenance manpower requirements for the baseline and alternative designs.

3. Operations manpower requirements.

4. Scope and magnitude of training and technical manuals for maintenance personnel

5. Scope of training for operations personnel.

6. System ownership cost (SOC) for baseline and alternative designs.

7. Human resources, logistics, and cost impact and high drivers.

8. Training and technical manual products for maintenance personnel.

Samples of data are included in the discussion or in Volume II as appropriate. Data developed were based on the same Required Operational Capability (ROC) used during the validation phase, which assumed 277 aircraft, 256 unit equipped (UE), and 21 not operationally available (NOA). Sixteen operational squadrons were split between four continental United States (CONUS) and two overseas locations. The training squadron was located at one of the CONUS bases. Aircrew/aircraft ratio was 2:1 per UE and per NOA used for training. Utilization rate was 1.8 hours/ day during a 5-day week.

2.3.1 Baseline and Alternative Designs Selected for Assessment

The first step accomplished in this phase was to update the design option decision trees (DODTs) to depict the latest system design and support plan. Samples of the DODTs for AMST system landing gear and avionics, as updated, are enclosed in Volume II. The logistics option tree, a DODT developed to indicate alternative logistics options, is also included in Volume II. The logistics option tree depicts the alternatives in SE, maintenance concept, personnel/ training/technical manual approach, and spares philosophy.

The second step was to identify a detailed system design (baseline equipment configuration) for both landing gear and avionics. At this point in the AMST acquisition, a decision had been made to require an avionics system capable of being operated by a flight deck crew composed of a pilot and copilot, the 2MFD avionics option. Tables 1 and 2 list part of the baseline configuration for landing gear and avionics respectively. Each listing identifies subsystem (e.g., HF radio set) within the major system (e.g., avionics), and the major LRUs (e.g., reciever/transmitter) within each subsystem. These tables present the equipment listings as they are retained in the hardware configuration/ characteristics data file of the CDB. The content of each column in the listing is fully explained in AFHRL-TR-79-65 (reference 6). For purposes of this report, however, it is sufficient to recognize that the parts of the major systems are listed under the column "quantity and descriptive term" and the data sources for the parts are listed under the column "aircraft reference." As previously stated, a specific configuration for AMST avionics and landing gear was not available and had to be projected. Tables 1 and 2 represent those projections and the aircraft reference represents the aircraft from which use and cost data for the major subsystem were obtained.

A portion of the information required to update the DODTs and identify the system design and support plan was obtained from the Air Force MED phase statement of work and system/ subsystem specifications included in the AMST RFP. These data were supplemented with historical maintenance and cost data on the reference aircraft. The objective was to develop the same degree of detail in the projected data as could be expected in the MED phase o that CHRT could be realistically demonstrated. A subse uent review of DODTs resulted in the identification of one system and four detailed baseline versus alternative sets.

At the system level, the conventional versus the task-oriented approach to personnel, training, and technical manuals was selected for the landing gear and for avionics. This is a viable system level option that was addressed in earlier acquisition phases and would be of continued interest in the MED phase. The more detailed information available in the MED phase would provide a much firmer basis for assessment and decision than earlier data. In order to consider the task-oriented approach, the baseline maintenance action networks which reflected the conventional approach were modified to reflect the task- oriented approach using the same set of guidelines used in earlier acquisition phases. These guidelines are included in Volume

Table 1 Baseline Configuration Projected AMST Landing Gear

COMPUTER DATA CODE	QUANTITY AND DESCRIPTIVE TERM	AIRCRAFT REFERENCE	
07			
CR GLG110 -1 13A00	2 MAIN LANDING GEAR	C141	4
CR GLG111 -12938.5 13AA0	2 MECHANICAL PARTS (MLG)		32
CR GLG112 -1 494.0 13AB0	2 HYDRAULIC PARTS (MLG)		19
CR GLG113 -1 10.0 13AC0	2 ELECTRICAL PARTS (MLG)		8
CR GLG114 -1 1.0 13AD0	2 MLG INSTRUMENTS		2
CR GLG120 -1 13B00	1 NOSE LANDING GEAR	C141	3
CR GLG121 -1 962.6 13BA0	1 MECHANICAL PARTS (NLG)		20
CR GLG122 -1 247.0 13BB0	1 HYDRAULIC PARTS (NLG)		10
CR GLG123 -1 5.0 13BC0	1 ELECTRICAL PARTS (NLG)		4
CR GLG130 -1 13C00	1 LANDING GEAR CONTROLS	C141	1
CR GLG131 -1 280.0 13CA0	1 ELECTRICAL PARTS (LGC)		11
CR GLG140 -1 13D00	1 BRAKES/ANTI-SKID	C141	3
CR GLG141 -1 4[illegible]3.7 13DB0	1 HYDRAULIC PARTS (BRAKES)		13
CR GLG142 -1 193.0 13DC0	1 ELECTRICAL PARTS (BRAKES)		3
[illegible]R GLG143 -1 115.0 13DA0	1 MECHANICAL PARTS (BRAKES)		10
GLG150 -1 13E00	1 STEERING SYSTEM	C141	2
[illegible]151 -1 133.0 13EB0	1 HYDRAULIC PARTS (STEERING)		3
[illegible]52 -1 50.0 13EA0	1 MECHANICAL P[illegible]TEERING)		11
-1 13F00	1 EMERGENC[illegible]	C141	2
40.0 13FA0	1 MLG [illegible]		14
2.0 13FB0	1 N[illegible]		1
13G00		[illegible]141	6
13[illegible]			3
			4

Table 2 Baseline Configuration Projected AMST Avionics

COMPUTER DATA CODE	QUANTITY AND DESCRIPTIVE TERM	AIRCRAFT REFERENCE	
CR FAC110 -1 61A00	1 HF RADIO SET	FB111	5
CR FAC111 -1 13.0 61AA0	1 RECEIVER/TRANSMITTER (HF)		13
CR FAC112 -1 23.0 61AB0	1 AMPLIFIER POWER SUPPLY (HF)		10
CR FAC113 -1 19.5 61BA0	1 ANTENNA COUPLER (HF)		[illegible]
CR FAC114 -1 13.5 61BC0	1 VARIABLE VACUUM CAPACITOR (HF)		1
CR FAC115 -1 4.1 61ADA	1 MOUNT (HF)		1
CR DAC210 -1 62140	1 VHF/FM RADIO	C-130E	3
CR DAC211 -1 33.0 6214C	1 RECEIVER-TRANSMITTER		[illegible]
CR DAC212 -1 8.0 6214A	1 FM ANTENNA		[illegible]
CR GAC220 -1 62B00	1 VHF/AM RADIO	C-141	2
CR GAC221 -1 68.5 62BB0	1 TRANCEIVER		1
CR GAC222 -1 3.0 62BAB	1 AM ANTENNA		4
CR CAC320 -1 63A00	1 UHF COMMUNICATIONS SET	C5	2
CR CAC321 -1 27.7 63AA0	1 RECEIVER TRANSMITTER (UHF)		11
[illegible]R CAC324 -1 2.0 63AC0	1 UHF SUBSYSTEM COMPONENTS		7
AAC310 -1 63B00	1 AUTO DIRECT FINDER / UHF	A-7D	3
[illegible]311 -1 5.4 63BA0	1 AMPL RELAY ASSY (ADF/UHF)		3
[illegible] -1 10.0 63BB0	1 ANTENNA (UHF[illegible]		1
-1 1.1 63BC0	1 MOUNT ([illegible]		1
64210	1 INTE[illegible]	C130E	2
9.4 6421B	1 S[illegible]		3
0 6421F			6
64[illegible]			4
			3

II. The important concept, however, is that the maintenance action networks reflect the support plan and must be modified to reflect and assess the impact of alternative support plans.

At the more detailed subsystem level, the following baseline designs versus alternative designs were selected.

1. Discrete versus combined VHF/AM and VHF/FM radios

2. Standard versus modified station-keeping equipment (SKE)

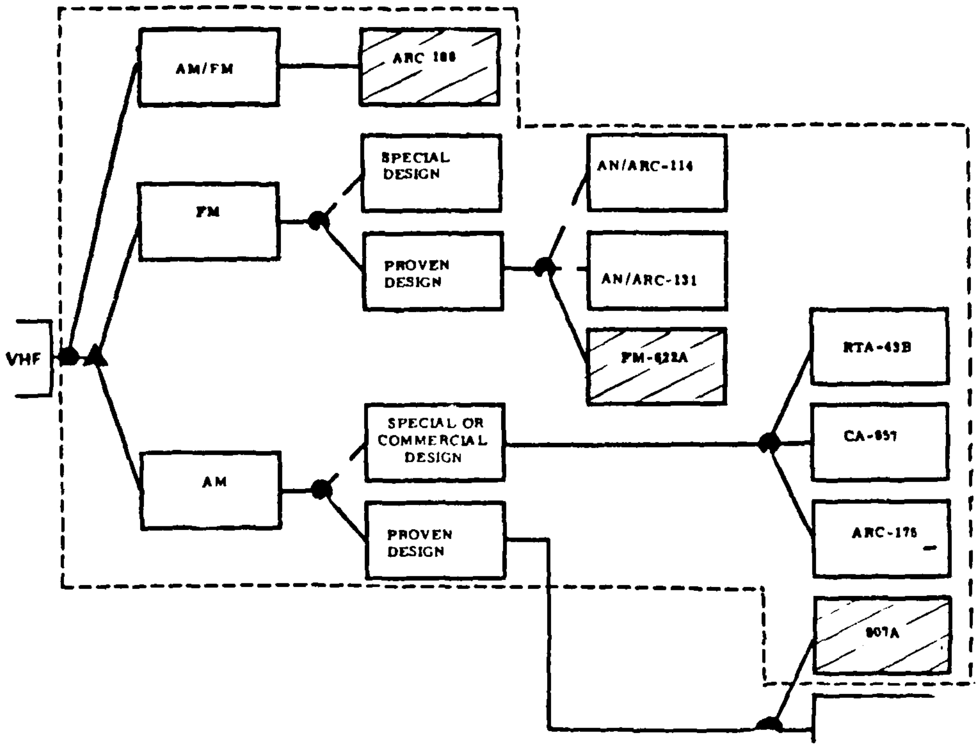
3. Carbon versus steel brakes

4. Higher order language (HOL) versus assembly software language.

These four subsystem level options were all identified in the design option decision trees. A discussion of each alternative set is provided in the following paragraphs.

2.3.1.1 Discrete Versus Combined VHF/AM and VHF/FM Radios

Figure 1 depicts and summarizes one subsystem level design comparison, the discrete (individually distinct) versus combined VHF/AM and VHF/FM radio. The DODT indicates a choice between a VHF/AM/FM radio, the ARC-186, or the VHF/AM and the VHF/FM radios, the 807-A and the FM-622A, respectively. The specific radios noted in the DODT were identified as potential alternative candidates in the AMST avionics study (NADC-78-82-60, reference 16). In order to provide simultaneous AM and FM capability, two ARC-186 radios will be required per aircraft. The summary information in Figure 1 indicates this fact along with the radio nomenclature, mean flight hours between maintenance actions (MFHBMA), mean time to repair on the flightline (MTTR-FL) and mean time to repair in the shop (MTTR-SHOP). The source for the ARC-186 data was Aeronautical Systems Division (ASD)/Deputy for Aeronautical Equipment (AEAC).



(1) VHF/AM	and	(1) VHF/FM	vs	(2) VHF/AM/FM
• 807-A		• FM-622A		• ARC-186
• 62 MFHBMA		• 400 MFHBMA		• 600 MFHBMA
• 2 HR MTTR-FL		• 1½ HR MTTR-FL		• 10 MIN MTTR-FL
• 6 HR MTTR-SHOP		• 4 HR MTTR-SHOP		• 40 MIN MTTR-SHOP

Figure 1

DODT and summary
discrete vs. combined VHF/AM/FM radios.

2.3.1.2 Standard Versus Modified SKE

Standard versus modified SKE represents a subsystem design comparison at the LRU level. A choice between a proven design, the APN-169B, and a special design, the APN-169X was noted in the DODT. A query to the manufacturer indicated that a special design was, in fact, being proposed to the Air Force. It included a modification to the original design which: (a) reduce the number of LRUs from eight to seven; (b) increase MFHBMA from 26.3 to 40.3 by improving the reliability of a critical LRU, the coder/decoder; and (c) reduce scheduled maintenance to a 360-day cycle from a 60-day cycle. The actual proposed research and development (R&D) cost was procurement sensitive at the time this alternative was addressed.

2.3.1.3 Carbon Versus Steel Brakes

A design comparison alternative at the shop replaceable unit (SRU) level is the carbon versus steel brake. These options are clearly indicated on the DODT, and reflect a change in material design. Significant research is presently being done on carbon brakes for fighter aircraft. Although this type brake is not yet considered economically feasible for transport aircraft, which are less dependent on brakes and thus require fewer brake changes, carbon brakes was an appropriate option on which to demonstrate the sensitivity of CHRT at the SRU level. The impact of the carbon brake over steel was estimated based on information obtained from the Aeronautical Systems Division, ASD/AEAC. Carbon brakes were assumed to reduce brake changes by one third, increase brake cost by a factor of four and require a considerable monetary investment in R&D.

2.3.1.4 HOL Versus Assembly Software Language

In new weapon systems, software system design and maintenance has become a significant issue. It was for this reason, therefore, that a software option was of special interest. A review of the software DODT indicated that two working language options were open during the AMST MED phase. These were machine (assembly) language and HOL. Software, however, was not directly addressed in the

original human resource technologies and receives only limited consideration in CHRT. The purpose here was to use the limited capability available to document a software assessment and to identify where improvements in assessment capability are desirable. The starting point for this assessment is an estimate shown in Table 3 which characterizes AMST computer memory requirements in terms of 16 bit words. The source of this estimate was reference 18.

Table 3 - Projected AMST Computer Memory Requirements

Software Routine	Memory (16 bit words)
Input Control Processing	0.5K
Computed Air Release Point	2.0K
Navigation Filter	1.5K
FCS Format Output	0.2K
Output Display Data	2.0K
CDR Interface	0.1K
On-Board Test	0.1K
Computer Self-Test	0.6K
Executive/MUX Control	2.0K
Utility Routines/Constants	1.5K
Weight/Balance	0.5K
Optimum Cruise	0.5K

2.3.2 Reliability, Maintainability, and Maintenance Manpower Requirements for Baseline and Alternative Designs

2.3.2.1 System Level Options - Reliability and Maintainability (R&M) Summaries

The AMST prototype phase maintenance action networks for the 2MFD avionics and modified C-141 landing gear were updated to reflect the projected AMST MED phase configuration. The update resulted in a more detailed equipment breakdown and revised maintenance times and failure probabilities. This update was accomplished using the more detailed design data and improved information available and/or assumed in the MED phase. All networks were prepared to reflect a conventional approach to personnel, training, and technical manuals; specifically, 5-skill-level manning supported by 3-skill-level helpers, conventional training, and conventional

technical manuals. An additional set of maintenance action networks reflecting the task-oriented option for the 2MFD avionics and landing gear was also updated. The task-oriented option assumes predominantly 3-skill-level manning on the flightline supported by task-oriented training and task-oriented technical manuals. All networks were used as input data for the R&M mode. The model was operated and reliability, maintainability, and maintenance manpower data were obtained for each avionics and landing gear option. The reliability and maintainability results calculated for the landing gear and for avionics, both with the conventional personnel, training, and technical manual option, are depicted in Tables 4 and 5, respectively. The first column identifies each subsystem within the major system. The remaining columns provide measures of reliability and maintainability which are:

1. Availability - calculated as $\frac{\text{MFHBMA}}{\text{MFHBMA + MTTR}}$
2. MFHBMA = mean flight hours between maintenance actions

3. FL R&R - flightline remove and replace time in hours

4. FL MTTR - flightline mean time to repair in hours

5. FL MMH - flightline mean time to repair man hours to repair

6. Shop MMH/FH - shop maintenance man hours per flying hour

Additionally,

7. MMR (which is not shown) - maintenance personnel required to effect a flightline repair may be calculated as $\frac{\text{FL MMH}}{\text{FL MTTR}}$

   Some common abbreviations used with the major item descriptors and not previously discussed are as follows:

HF	high frequency	ILS	instrument landing system
UHF	ultra high frequency	LF	low frequency

DF	direction finder	INS	inertial navigation system
IFF	identification friend or foe	HUD	heads up display
TACAN	tactical air navigation system	CRT	cathode ray tube system
VOR	visual omni range		

A comparison of the data in Table 4 with similar data developed in the prototype phase shows no difference in R&M requirements for the landing gear. This is understandable since the basic configuration and input data remained the same. A major improvement in landing gear data is in LRU and SRU count and in input cost data, which directly affect the technical manual page estimates and system ownership cost estimates.

A comparison of Table 5 with similar data developed in the prototype phase, however, does show differences in R&M requirements. This is due to the following minor configuration changes which reflect improved data in the MED phase: (a) HF, UHF, and VHF navigation radios were reduced from two to one; (b) secure voice and LF/DF were eliminated; (c) the combined VOR/ILS configuration was more correctly presented as separate VHF navigation and glide slope receiver subsystems; and (d) the separately integrated communication and navigation control panels were assumed to be one fully integrated unit with solid state electronic reliability.

Tables 6 and 7 depict the R&M summaries for the task-oriented option for landing gear and avionics, respectively. The system design remains the same as that described by Tables 4 and 5. There is, however, a support design change which is the task-oriented approach. The effect of this support design change is reflected in Tables 6 and 7. For example, if the main gear in Table 6 is compared with respect to the main gear in Table 4, differences are apparent in each category except shop MMH/FH. Similar differences are apparent in a comparison of Tables 5 and 7 which address avionics. The differences are the result of the data differences that exist on the maintenance action networks for "conventional" support versus the maintenance action networks for "task-oriented" support.

Table 4 R&M SUMMARY – LANDING GEAR

CONVENTIONAL PERSONNEL, TRAINING, AND TECHNICAL MANUAL OPTION

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH	FL MMH/FH	Shop MMH/FH
Main Gear	.9284	29.0	0.45	2.24	9.64	0.33	0.03
Nose Gear	.9535	56.0	0.85	2.73	10.94	0.20	0.01
Controls	.9857	189.0	0.95	2.74	7.48	0.04	0.01
Brakes/Anti-Skid	.7451	9.0	0.60	3.08	15.39	1.71	0.23
Steering System	.9568	74.0	0.96	3.34	10.03	0.14	0.01
Emergency Systems	.9979	819.0	0.14	1.72	3.44	0.004	–
Wheels & Tires	.9258	22.0	1.75	1.76	3.51	0.16	0.14

Table 5 R&M SUMMARY – AVIONICS

CONVENTIONAL PERSONNEL, TRAINING, AND TECHNICAL MANUAL OPTION

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH	FL MMH/FH	Shop MMH/FH
HF Radio	.7673	15.0	2.62	4.55	13.64	0.909	0.160
VHF/FM Radio	.9968	400.0	0.94	1.27	3.80	0.010	0.006
VHF/AM Radio	.9608	52.0	0.74	2.12	6.37	0.122	0.126
UHF Radio	.9681	81.0	1.04	2.67	8.01	0.099	0.021
UHF-ADF	.9983	800.0	0.17	1.33	5.16	0.006	0.001
Intercom	.7463	6.0	0.55	2.04	6.12	1.020	0.114
Public Address	.9881	306.7	0.66	3.70	12.56	0.041	0.002
IFF	.9846	200.0	1.01	3.14	9.41	0.047	0.006
IFF Computer	.8998	35.0	0.70	3.90	11.70	0.334	0.060
Crash Position	.9515	47.0	0.91	2.39	9.58	0.204	0.054
TACAN	.9870	164.0	1.78	2.17	6.50	0.040	0.046
VHF Navigation	.9843	117.0	0.70	1.87	5.61	0.048	0.002
Glideslope	.9843	117.0	0.70	1.87	5.61	0.048	0.002
Radar Altimeter (2)	.9876	187.0	1.23	2.35	7.06	0.038	0.005
OMEGA	.8889	29.0	1.38	3.63	10.88	0.375	0.363
RADAR	.6280	6.0	1.73	3.55	12.82	2.136	0.963
SKE	.8981	26.3	1.26	2.99	9.98	0.379	0.058
INS	.9094	22.0	0.88	2.19	6.58	0.299	0.128
Micro HUD (2)	.8928	28.0	1.42	3.36	10.09	0.360	0.254
Int. Nav. Sig. Converter	.9114	28.0	1.46	2.72	8.16	0.292	0.059
Int. Comm/Nav Control	.9969	60.0	0.05	0.19	0.37	0.006	0.004
Mission Computer	.9015	31.0	1.20	3.39	10.16	0.328	0.147
CRT (3)	.9457	40.0	1.28	2.30	6.89	0.172	0.033
Digital Scan Conv.	.9789	139.0	1.66	3.00	8.00	0.065	0.042

Table 6 R&M SUMMARY – LANDING GEAR

TASK-ORIENTED PERSONNEL, TRAINING, AND TECHNICAL MANUAL OPTION

Item	Availability	MFHBMA	R&R	FL MTTR	FL MMH	FL MMH/FH	Shop MMH/FH
Main Gear	.9385	32.2	0.49	2.12	9.02	0.28	0.03
Nose Gear	.9588	62.2	0.94	2.67	10.48	0.17	0.01
Controls	.9870	211.2	1.06	2.77	7.34	0.36	0.01
Brakes/Anti-Skid	.7633	9.2	0.61	2.85	14.26	1.55	0.22
Steering System	.9608	74.7	0.97	3.05	9.14	0.12	0.01
Emergency Systems	.9982	853.1	0.14	1.58	3.15	0.004	–
Wheels & Tires	.9259	22.0	1.75	1.76	3.51	0.16	0.14

Table 7 R&M SUMMARY – AVIONICS

TASK-ORIENTED PERSONNEL, TRAINING, AND TECHNICAL MANUAL OPTION

Item	Availability	MFHBMA	FL R&R	FL MTTR	FL MMH	FL MMH/FH	Shop MMH/FH
HF Radio	.7911	16.6	2.65	4.38	13.15	0.792	0.149
VHF/FM Radio	.9969	400.0	0.94	1.24	3.71	0.009	0.006
VHF/AM Radio	.9661	61.9	0.88	2.17	6.51	0.105	0.120
UHF Radio	.9709	85.3	1.04	2.55	7.66	0.090	0.020
UHF ADF	.9984	800.0	0.16	1.24	4.79	0.006	0.001
Intercom	.7671	6.5	0.59	1.97	5.92	0.911	0.113
Public Address	.9898	340.8	0.68	3.50	11.94	0.035	0.001
IFF	.9876	248.4	1.18	3.12	9.37	0.038	0.006
IFF Computer	.9167	39.5	0.69	3.59	10.77	0.273	0.057
Crash Position	.9582	55.6	0.98	2.38	9.51	0.171	0.075
TACAN	.9873	164.0	1.77	2.11	6.33	0.039	0.014
VHF Navigation	.9875	161.4	0.95	2.04	6.13	0.038	0.003
Glideslope	.9875	161.4	0.96	2.05	6.15	0.038	0.002
Radar Altimeter (2)	.9893	204.4	1.20	2.21	6.63	0.032	0.004
OMEGA	.9050	34.1	1.51	3.58	10.74	0.315	0.352
RADAR	.6433	6.3	1.72	3.42	12.36	1.962	0.209
SKE	.9100	29.4	1.38	2.91	4.75	0.162	0.072
INS	.9214	25.1	0.91	2.14	6.42	0.256	0.120
Micro HUD (2)	.9089	32.0	1.47	3.22	9.67	0.302	0.234
Int. Nav. Sig. Converter	.9276	31.5	1.29	2.46	7.37	0.234	0.052
Int. Comm/Nav. Control	.9971	64.9	0.05	0.19	0.38	0.006	0.004
Mission Computer	.9148	34.4	1.20	3.21	9.61	0.279	0.140
CRT (3)	.9514	42.1	1.24	2.15	6.45	0.153	0.031
Digital Scan Conv.	.9808	146.3	1.62	2.86	8.58	0.059	0.040

2.3.2.2 System Level Options - Maintenance Manpower Requirements

Maintenance manpower requirements are determined for each AFSC in terms of maintenance hours per thousand flying hours (MMH/KFH) directly from the R&M model. The average number of personnel required per squadron for each AFSC and skill level is determined from the following formula.

Number of Personnel

$$= \frac{(\text{MMH/KFH})\ (\text{FH/SQ-YR})\ (\text{YR/12 months})}{(\text{Efficiency factor})\ (\text{work days/month})\ (\text{shift hours/day})}$$

where:

MMH/KFH = maintenance hours/1000 flying hours

FH/SQ-YR = flying hours/per squadron-year = 7488 flying hours/year

YR/12 months = 1 year/12 months = .083 year/month

Efficiency factor = .6 (reference 13)

Work days/month = 5 days/week • 4.33 weeks/months = 21.7 maintenance days/month

Shift hours/day = 8 maintenance hours/maintenance day

The variables FH/SQ-YR, efficiency factor, work days/month, and shift hours/day represent a scenario. The scenario used for this demonstration was 1.8 FH/aircraft-day, 16 aircraft/squadron, 5 flying days/week, .6 efficiency factor, 21.7 work days/month, and 8 shift hours/work day. The source of the scenario data was the Employment Concept for the Advanced Medium STOL Transport (reference 18). The major factor not considered in this scenario is the planned sortie rate and duration. The R&M model which was used to obtain these estimates assumes an average value of 1.8 FH per assigned aircraft. The R&M model does not consider the mission dynamics, such as variable sortie intervals and duration.

Table 8 and 9 present maintenance manpower requirements for landing gear and avionics, respectively. Requirements are presented in terms of maintenance manhours per thousand

Table 8 MAINTENANCE MANPOWER REQUIREMENTS LANDING GEAR

		Conventional		Task-Oriented	
AFSC	Title	MMH/KFH	MMPWR/SQ	MMH/KFH	MMPWR/SQ
42350	Aircraft Electrical	508.97	3.05	186.85	1.12
42330	Systems	348.08	2.09	586.12	3.52
42354	Aircraft Pneudraulics	626.65	3.75	260.55	1.56
42334		230.19	1.38	506.90	3.04
43151	Aircraft Maintenance	609.88	3.66	554.56	3.33
43131		248.41	1.49	240.36	1.44
4315W	Aircraft Maintenance	55.27	.33	55.27	.33
4313W	(Wheels)	42.15	.25	42.15	.25
4315R	Aircraft Maintenance	147.16	.88	127.31	.76
4313R	(Reclamation)	12.41	.07	10.80	.06
53150	Machinist	3.41	.02	3.42	.02
53154	Corrosion Control	84.08	.50	83.96	.50
53134					
53155	Non-Destructive	84.24	.51	84.05	.50
53135	Inspection	0.17	–	0.08	–

Table 9 – MAINTENANCE MANPOWER REQUIREMENTS AVIONICS

		Conventional		Task-Oriented	
AFSC	Title	MMH/KFH	MMP/SQ	MMH/KFH	MMP/SQ
32650A	Avionics Support	143.33	0.86	143.86	0.86
32630A	Equipment–Manual	143.33	0.86	143.86	0.86
32650B	Avionics Support	73.42	0.44	73.48	0.44
32630B	Equipment–Automatic	73.42	0.44	73.48	0.44
32850	Avionics Communications	1594.51	9.57	535.48	3.21
32830		847.78	5.09	1672.48	10.03
32851	Avionics Navigation	1542.71	9.26	596.51	3.58
32831		1173.75	7.04	1874.96	11.25
32854	Avionics Inertial &	853.76	5.12	369.45	2.22
32834	Radar Navigation	746.17	4.48	1034.99	6.21
42350	Aircraft Electrical	3.37	0.02	3.38	0.02
42330	Systems	3.37	0.02	3.38	0.02
43151	Aircraft Maintenance	2195.27	13.17	1920.60	11.52
53150	Machinist	63.33	0.38	63.23	0.38
53153	Airframe Repair	31.62	0.19	30.73	0.18
53133		23.21	0.14	22.93	0.14

flying hours (MMH/KFH) and maintenance manpower per squadron (MMP/SQ) for each AFSC required. A comparison of the landing gear data in Table 8 with validation phase results shows no difference. This is because there was no change in the landing gear between the validation phase and the full-scale development phase. A comparison of the avionics data in Table 9 with validation phase results does reflect a difference. This difference is due to the system design changes implemented in the MED phase and reflects the CHRT sensitivity to design changes.

A comparison of the conventional versus task-oriented personnel, training, and technical manual option in each table reveals a difference in both quantity and skill level of personnel requirements. This difference results from the support plan alternative represented by the two options.

2.3.2.3 Subsystem Level Options

During the validation phase demonstration, a technique was developed to isolate a single subsystem from a system maintenance network, and then to address that subsystem and its design alternative in terms of both scheduled and nonscheduled maintenance. The technique was successfully used during the validation phase in a single subsystem. The technique was used more extensively in this part of the demonstration on three subsystem design problems. This application is discussed in the following paragraphs.

The first assessment is the comparison of discrete VHF/AM and VHF/FM radio subsystem with a combined VHF/AM/FM radio subsystem. A description of the configuration of these alternatives is provided in Table 10 which lists the subsystem or major LRU identifier, the quantity of each and the name of the subsystem or major LRU. In the identifier column, a three-digit number ending in zero identifies each subsystem. A 1 through 9 in the third place indicates a major LRU within a subsystem.

A maintenance action network[5] reflecting unscheduled maintenance was prepared for each radio design option. The

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[5] A brief description of maintenance action networks is provided in Appendix A.

Table 10 - VHF Radio Alternative
Discrete VHF Radios vs. Combined VHF Radios

Discrete			Combined		
Identifier	Quantity	Name	Identifier	Quantity	Name
GAC220	(1)	VHF/AM Radio	XAC230	(1)	VHF/AM/FM Radio
GAC221	(1)	Transceiver	XAC231	(2)	Receiver
GAC222	(1)	AM Antenna	XAC232	(1)	AM Antenna
DAC210	(1)	VHF/FM	XAC233	(1)	FM Antenna Radio
DAC211	(1)	Receiver-Transmitter	XAC234	(2)	Mounting Unit
DAC212	(1)	FM Antenna			

networks for the discrete VHF/AM and VHF/FM radios are shown in Figure 2. These networks were based on C-141 data. The data represented by these networks were used with the R&M model to quantify reliability, maintainability, and maintenance manpwoer requirements. A separate network was then developed to reflect the combined design option. This network (shown in Figure 3) is based on information and data obtained from avionics engineers at the Aeronautical Systems Division. The use of 300 hours for MFHBMA rather than the 600 hours specified per unit is an adjustment made to account for the fact that the combined VHF subsystem has two receiver-units. The combined option was then assessed using the R&M model.

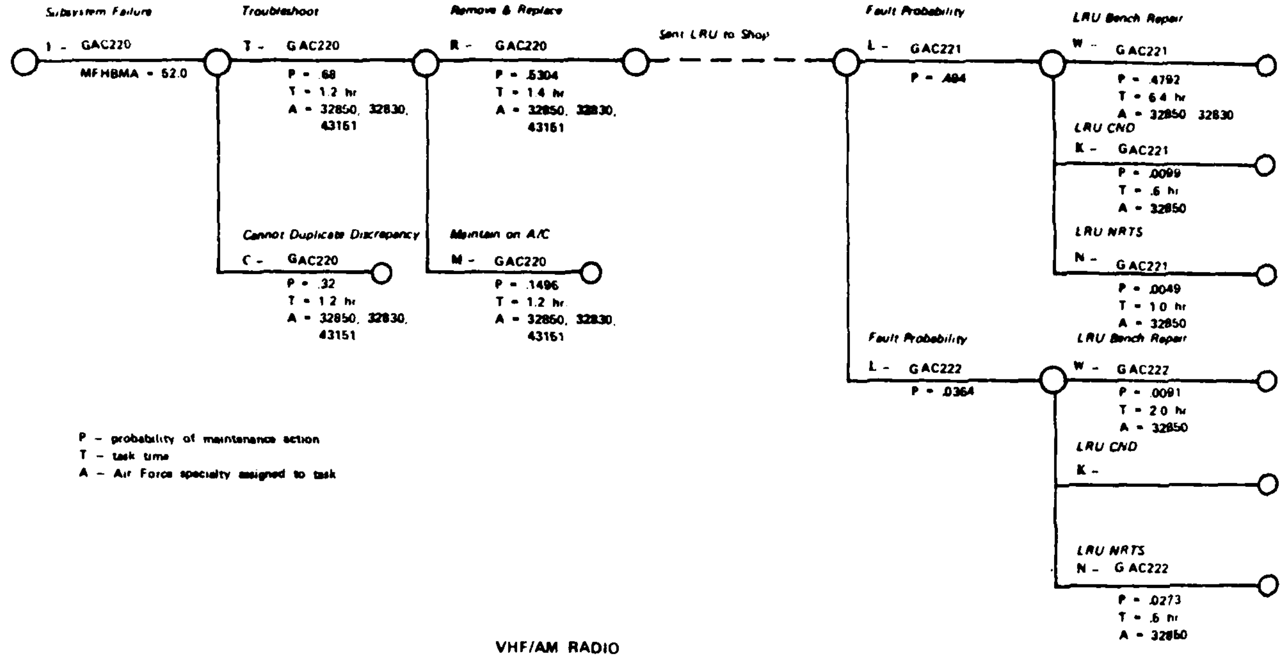
A comparison of the results is shown in Table 11.

Table 11 - Reliability, Maintainability and Manpower Assessment VHF Radio Alternative

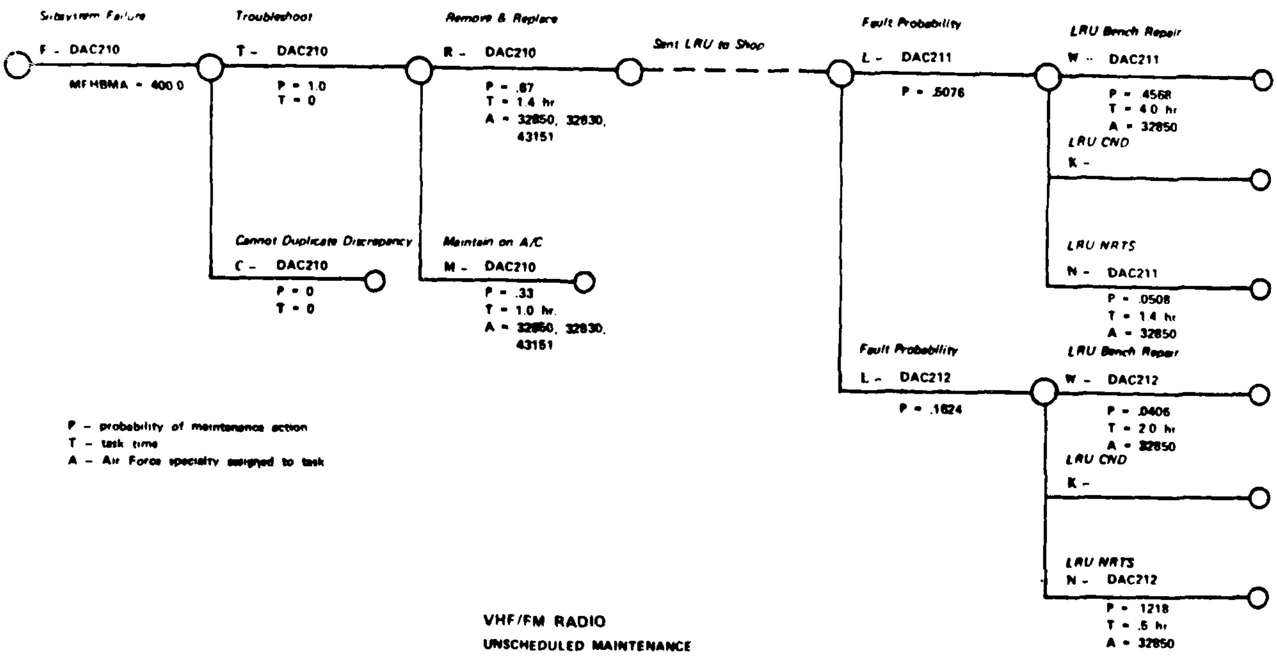
	Discrete Option	Combined Option
Availability	0.9578	0.9989
MFHBMA	46	300
MMH/FH(S)	0.124	0.0016
MMH/FH(F/L)	0.132	0.0023
MTTR	8.5	0.82
Maint. Personnel (17 Squadrons)	26	0.3
5 Level	15	0.2
3 Level	11	0.1

The low probability of failure and low time to repair on the combined option substantially reduce the need for maintenance personnel. These results were supported by the findings of a review of the specification for the ARC-186, VHF AM/FM radio. It was procured on a reliability improvement warranty (RIW) with one objective being the reduction of maintenance requirements.

The second assessment, using the R&M model, is a comparison of the standard SKE with a modified SKE subsystem. In this case, the standard SKE network, based on C-130 data, was isolated from the avionics system and was assessed for unscheduled maintenance. A similar network, based on data from the manufacturer, was prepared to reflect the modified



VHF/AM RADIO
UNSCHEDULED MAINTENANCE



VHF/FM RADIO
UNSCHEDULED MAINTENANCE

Figure 2 VHF radio alternative - The discrete option.

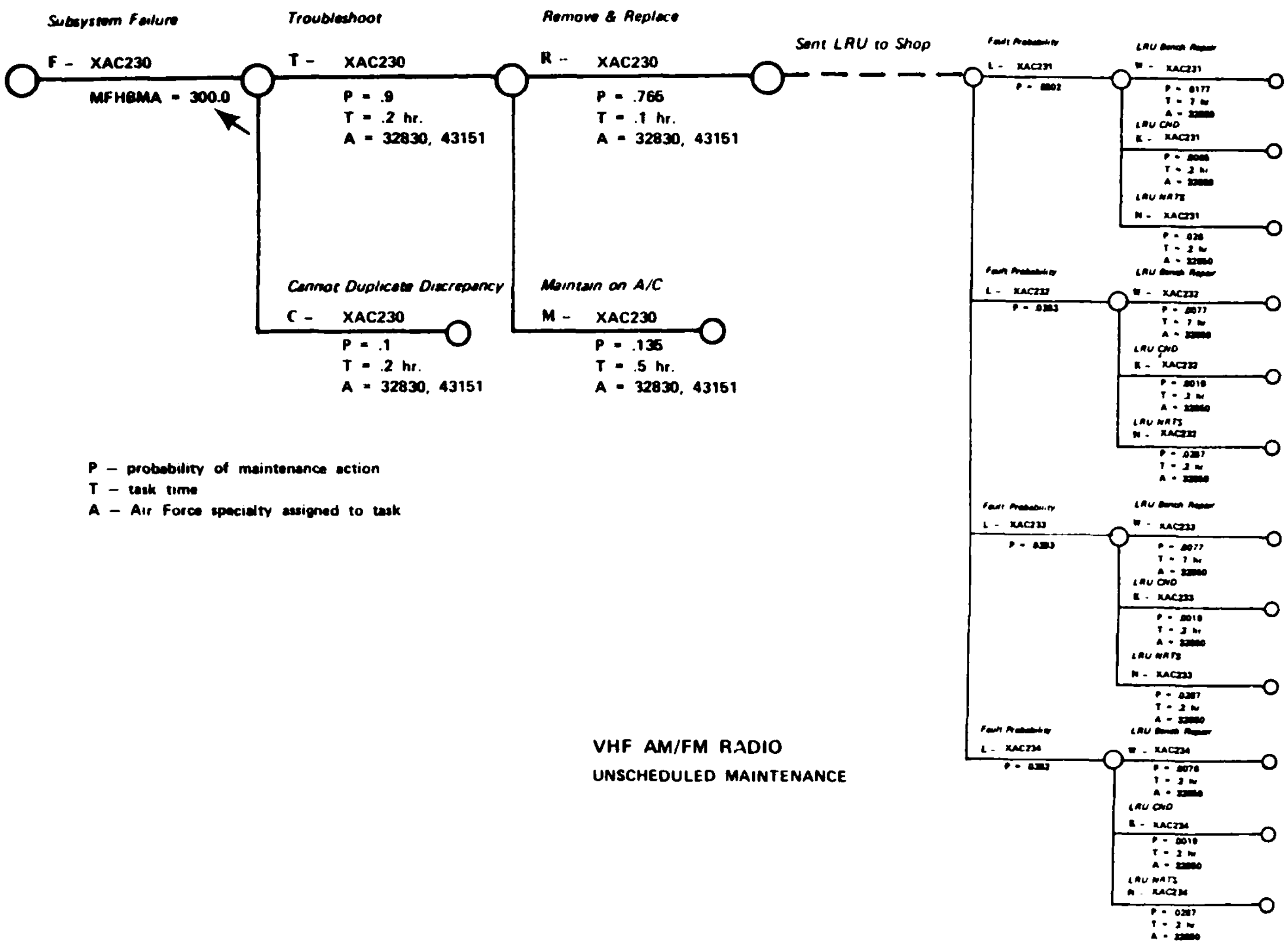


Figure 3 VHF radio alternative - The combined option.

SKE; it also was assessed for unscheduled maintenance. In both cases, reliability, maintainability, and maintenance manpower requirements were quntified. The major differences depicted in these networks were an increase in MFHBMA from 26.3 in the standard design to 40.3 in the modified design and, a reduction in coder/decoder fault probability from .3331 in the standard design to .1732 in the modified design. These differences are directly attributable to the increased equipment reliability and the elimination of one LRU.

Scheduled maintenance on the coder/decoder is also an important factor to consider in this assessment. Therefore, scheduled maintenance networks were prepared for the coder/decoder for both designs. The factor, MFHBMA, in this case represents the scheduled maintenance rate in terms of flying hours assuming each aircraft flies 400 hours a year. Therefore, a scheduled MFHBMA of 400 hours reflects scheduled maintenance once a year while 66 hours reflects scheduled maintenance approximately every 60 days. Maintenance time is expended in each scheduled maintenance action to check out the item of equipment on the aircraft prior to removal and after replacement, to remove and replace the item, and to bench check the item. The MFHBMA increased from 19.7 for the standard design to 36.6 for the modified design.

The results of the R&M model assessments for unscheduled and scheduled maintenance requirements for both options are shown in Table 12. The results show a substantial increase in availability and reduction in manpower requirements with the modified option. This has been achieved by improved reliability and reduced scheduled maintenance. No action has been taken here to specifically improve maintainability. If further reductions in manpower were desired, maintainability would be an area to consider.

The third assessment is the comparison of steel versus carbon as brake material. The brakes are part of the brakes/ anti-skid subsystem of the landing gear system. A single anti-skid design configuration is used in this analysis. The network representing this design did not differentiate among specific parts or LRUs because such detailed data could not be realistically projected for the AMST. Instead, a differentiation was made among functional part groupings, such as hydraulic, electrical, and mechanical parts.

Table 12 - Reliability, Maintainability and Manpower Assessment SKF Alternative

	Standard Option	Modified Option
Availability	0.8946	0.9303
MFHBMA	19.7	36.6
MMH/FH(S)	0.15	0.08
MMH/FH(F/L)	0.18	0.12
MTTR	7.64	7.56
Maint. Personnel		
(17 Squadrons)	34	20
5 Level	23	13
3 Level	11	7

The mechanical parts include the brake rotors and stators, the parts directly affected by the choice of material. Use of carbon rotors and stators reduces brake wear by one-third over brakes using steel rotors and stators. Two maintenance action networks were prepared, one for carbon and one for steel brakes. The data within the carbon network were adjusted to represent one-third less wear. It was apparent immediately that this reduced brake wear had little impact on the MFHBMA for the brakes/anti-skid subsystem. Use of a carbon brake increased MFHBMA by only .2 hour, from 9.0 hours to 9.2 hours. The R&M model, however, is sensitive to such a minor difference. A comparison of results is shown in Table 13.

Table 13 - Reliability, Maintainability and Manpower Assessment Brake Material Option

	Steel Brakes	Carbon Brakes
Availability	0.7451	0.7493
MFHBMA	9.0	9.2
MMH/FH(S)	0.226	0.225
MMH/FH(F/L)	1.171	1.673
MTTE	4.0	4.0
Maint. Personnel		
(17 Squadrons)	198	194
5 Level	128	126
3 Level	70	68

The obvious conclusion is that there is no significant impact on reliability, maintainability, or manpower requirements by using carbon brakes even though one is longer wearing. The brakes would have to be replaced much more often to show an advantage to the carbon brake. The carbon brake, therefore, may have advantage in a fighter aircraft where landings are more frequent and reverse thrust is not available to supplement stopping capability and to reduce brake wear.

The final subsystem level alternative is the use of assembly language versus HOL for the avionics software programs. Assessments are provided in terms of cost only. The discussion of this alternative will be provided in the system ownership cost section of this report.

2.3.3 Operations Manpower Requirements

Operations manpower requirements were reviewed in this phase. The requirements identified in the prototype phase for the three member flight crew remained valid and are presented in Table 14. The technique used to develop these data was the same as that applied in the conceptual phases. The operations manpower data were used in the life cycle cost analyses which are discussed in a later section.

2.3.4 Scope and Magnitude of Training and Technical Manuals for Maintenance Personnel

During the early full-scale development phase, training course duration and technical manual content for avionics and landing gear maintenance personnel were reassessed. The techniques used were the same as those developed and used during the earlier phases of the study. Although actual equipment was still not available during full-scale development, knowledge of the hardware configuration and required maintenance skills was improved. Therefore, estimates may be made with greater accuracy. During this demonstration phase, the training and technical manual estimates were reaccomplished for the conventional and task-oriented logistics options on both the avionics and landing gear systems.

Table 14 OPERATIONS MANPOWER REQUIREMENTS LIST PER FY

	83	84	85	86	87	88	89	90-02	03	04	05	06	07	08	09
Crews to be Trained	8	32	84	132	136	155	119	54	54	54	0	0	0	0	0
Total Operations and Instructor Crews Required	8	40	120	240	352	472	544	544	540	508	432	312	192	72	0

Crew Composition

Pilot

Copilot

Loadmaster

BASIC REQUIREMENT

2-Crews/Aircraft

256 Unit Equipped Aircraft Peak

16–Training Aircraft Peak

TRAINING REQUIREMENT DERIVATION

FY83-89 New Crew Requirement + 10% Turnover

FY90-04 10% Turnover

FY05-09 10% Turnover Satisfied by Reassignment

2.3.4.1 Training

The course duration estimates for all the AFSCs required to support the landing gear and avionics systems are depicted in Table 15. These estimates remain the same as those calculated in the conceptual phase. This is due to the fact that no significant changes in the skills estimated at that time have occurred. The AMST is basically a conventional aircraft with no major requirement for new skills. Estimates are provided for both conventional and task-oriented training. The techniques used to obtain these estimates have been discussed in AFHRL-TR-79-28, Volume I (reference 9).

2.3.4.2 Technical Manuals

The determination of number and type(s) of pages required for avionics and landing gear technical manuals was accomplished by algorithms (AFHRL-TR-79-28 Volume I, reference 9) which are based on (a) type of technical manual, i.e., *conventional or task-oriented*; (b) type of system, i.e., mechanical/hydraulic or electrical; and (c) subsystem, LRU, and SRU count. The results are representative of early full-scale development and reflect the latest subsystem, LRU, and SRU count. The full-scale development phase results are provided in Tables 16 (avionics) and 17 (landing gear). Table 17 represents results in computer output format. Both tables present page quantity estimates. Both tables also differentiate between troubleshooting and nontroubleshooting, and within each of those categories, between flightline and shop. Shop values are the same for conventional and task-oriented manuals, because the data were calculated in both cases using only conventional manuals. It was assumed that task-oriented manuals would not be used in the shop.

Cost estimates for these manuals were derived and are given in a later section of this report. Cost estimates are based on individual page costs developed from a detailed analysis of page types (reference 14). Page costs include page preparation, verification and validation, and contract loading.

In the late full-scale development phase, actual hardware becomes available and a task analysis may be performed on this equipment. The task analysis results may be used to

Table 15 - Training Course Duration

AFSC	Title	Course Length Conventional	Course Length Task Oriented
32850	Avionics Comm		
32830		28 wks	13 wks
32851	Avionics Nav		
32831		30 wks	13 wks
32854	Avionics Inertial &		
32834	Radar Nav	27 wks	15 wks
42350	Aircraft Electrical		
42330	Systems	19 wks	11 wks
42354	Aircraft Pneudraulics		
42334		11 wks	8 wks
43151	Aircraft Maintenance		
43131		11 wks	8 wks
53150	Machinist		
53153	Airframe Repair		
53133		13 wks	8 wks
53154	Corrosion Control		
53134			
53155	Non-Destructive	3 wks	2 wks
53135	Inspection	14 wks	10 wks

Table 16 Technical Manual Page Quantity and Type Estimate Avionics

Conventional Manuals

Page Type	TS F/L	TS Shop	NTS F/L	NTS Shop
narrative	144	239	240	876
half tone art	80	279	40	239
half tone explosion		239		40
electronic line art	80	874		437
exploded line art		160		
fault isolation chart				
fault isolation schematic block				
access line art				
fault isolation schematic flow				
fault isolation schematic mech/hyd				
job guide narrative				
job guide illustrations				
TOTALS	304	1791	280	1592

Subsystems	24
LRUs	80
SRUs	397

Table 16 - Technical Manual Page Quantity and Type Estimate Avionics (continued)

Task-Oriented Manuals

Page Type	TS F/L	TS Shop	NTS F/L	NTS Shop
narrative	40	239		876
half tone art		279		239
half tone explosion		239		40
electronic line art		874		437
exploded line art		160		
fault isolation chart	208			
fault isolation schematic block	48			
access line art	160			
fault isolation schematic flow	80			
fault isolation schematic mech/hyd				
*job guide narrative				800
*job guide illustrations				800
TOTALS	536	1791	1600	1592

*5 x 8 size

Table 17 Technical Manual Page Quantity and Type Estimate Landing Gear

Tech Manual Content Estimate Mech/ Hydro - Conventional

Page Type	TS F/L	TS Shop	NTS F/L	NTS Shop
narrative	116	62	316	233
half tone art	11	93	11	
half tone explosion	93		93	11
electornic line art				7
fault isolation chart				
fault isolation schematic block		21		
access line art				
fault isolation schematic flow				7
fault isolation schematic mech/hyd		21		
job guide narrative				
job guide illustrations				
TOTALS	219	197	419	257

Subsystems	7
LRU	21
SRU	186

Table 17 - Technical Manual Page Quantity and Type Estimate Landing Gear (continued)

Tech Manual Content Estimate
Mech/Hydro - Task-Oriented

Page Type	TS F/L	TS Shop	NTS F/L	NTS Shop
narrative	93	62		233
half tone art		93		
half tone explosion				11
electornic line art				7
exploded line art				
fault isolation chart	207			
fault isolation schematic block		21		
access line art	186			
fault isolation schematic flow				7
fault isolation schematic mech/hyd		21		
job guide narrative			1860	
job guide illustrations			1860	
TOTALS	486	197	3720	257

Subsytems	7
LRU	21
SRU	186

determine the information content of both the training program and the technical manual and then are used in the actual development of the training course and technical manuals. Also with task analysis data, estimates for training course length and technical manual volume may be improved based on actual equipment knowledge.

During this full-scale development phase demonstration, a task analysis was performed on actual equipment, the C-141 landing gear wheel and brake. The C-141 gear was used because it was representative of the gear that was proposed for the AMST. The purpose of the task analysis was to demonstrate and document a methodology for a single integrated task analysis that could be used for the development of a coordinated training program and technical manual set. The task analysis performed during this demonstration was accomplished for a limited task area, the wheel and brake removal and replacement task. Consequently, a reestimation of the total avionics and landing gear training program and technical manual content could not be made. Information content for the specific task, however, was determined and a single coordinated training plan and technical manual set for wheel and brake removal and replacement were developed. This training plan and technical manual set are discussed in a latter section of this report.

2.3.5 Scope of Training for Operations Personnel

As part of the full-scale development phase demonstration, the aircrew task lists developed in the conceptual and validation phases wre more thoroughly analyzed in order to determine pilot mission training requirements. From this information an estimate was made of length of mission training for pilots. The full-scale devleopment phase estimate is presented in Table 18. This length of training data was used in life cycle cost analyses which are discussed in a later section.

2.3.6 System Ownership Cost for Baseline and Alternative Designs

The previous sections have dealt with the assessments of reliability, maintainability, manpower requirements,

training course duration, and technical manual content for several system and subsystem design options. These are the human resource and logistics factors referred to in the title of this report. These must be known before the cost factors also referred to in the title can be determined. SOC are the costs of specific interest in CHRT, because they are driven directly by human resource and logistics considerations.

Table 18 - Operator Course Length

Phase	Segment	Duration*
Mission	Classroom	8
	Flying	28
	Written	1

* assumes 5-day week schedule but also includes weekend off time.

SOC are derived using the reliability, maintainability, and cost model (RMCM), which is documented in AFHRL-TR-79-65 (references 5 and 6). Althought the RMCM computes life cycle costs (LCC), the model has its greatest strength in the SOC area because it draws on the modeled maintenance system represented by the maintenance action networks and also on an operational scenario. This is a major advantage of the RMCM over many existing cost models. An additional advantage of the RMCM is that it also uses many standard cost data sources such as Air Force Regulation 173-10 (reference 13).

The RMCM consists of 23 cost elements similar to the cost elements of existing Air Force Logistics Command (AFLC) models. These cost elements cover all relevant costs associated with the development, acquisition, ownership, and disposal of the system. The hierarchical structure of these life cycle cost (LCC) elements, and their contributions to the categories used to catalog them, is shown in Figure 4. These cost elements are aggregated by a major cost category structure best suited for comparing LCCs. These are three

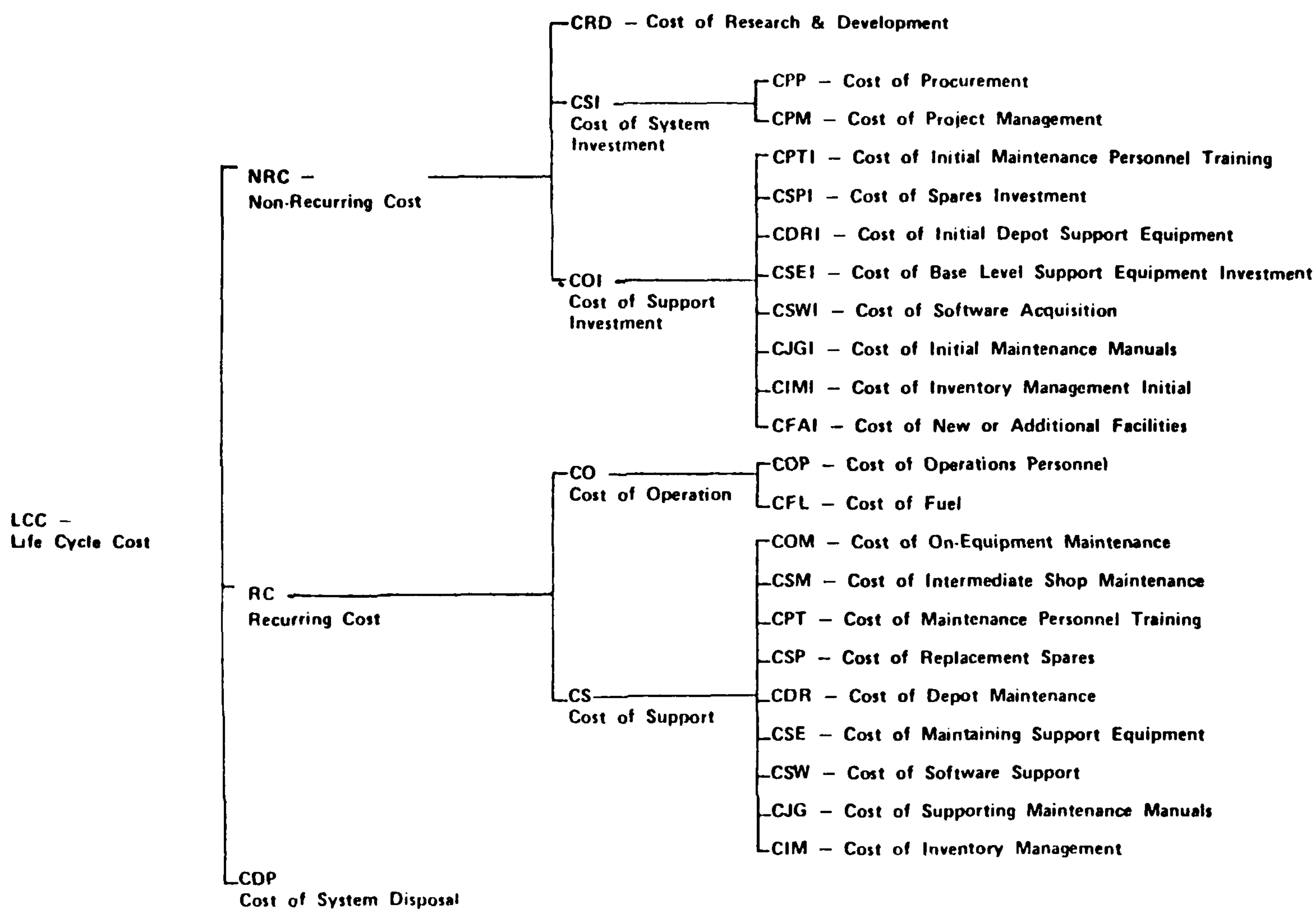


Figure 4 RMCM life cycle cost element structure.

principal categories of life cycle cost: (a) non-recurring, (b) recurring, and (c) system disposal.

The LCC estimate is presented in a series of 10 user-selected computer printout reports. These are:

Report No. 1 - System Cost

Report No. 2 - Expanded Non-Recurring Costs

Report No. 3 - Expanded Recurring Costs

Report No. 4 - Costs by Subsystem Contributions

Report No. 5 - Cost by LRU Contributions

Report No. 6 - Reliability, Maintainability and Availability by Subsystem

Report No. 7 - Manhour Costs/Year by AFSCs and Subsystem Supported

Report No. 8A - Spares Requirements - Investment

Report No. 8B - Spares Requirements/Year - Replacement

Report No. 9 - Support Equipment Requirements/Cost

Report No. 10 - Cost of Training

A set of these RMCM reports was prepared for all alternatives considered during ths phase of the demonstration except the HOL versus assembly software alternative. These cost data were summarized and are presented in Tables 19 and 20. All costs are in 1978 dollars. A complete report set for the standard station keeping equipment is provided in Volume II.

The reader may note that an estimate is provided for software acquisition and software support within the total avionics estimate (Table 19). That estimate was obtained for the assembly software language alternative using the RMCM cost of software acquisition and cost of software support equations given in AFHRL-TR-79-65 (reference 5).

Table 19 – Cost Summary System Level Options

	L/G[6] Conventional	L/G Task-Oriented	Avionics Conventional	Avionics Task-Oriented
R&D COST			0	0
SYSTEM INVESTMENT (millions $)				
Hardware	69,634	69,634	141.848	141.848
Project Management	–	–	–	–
TOTAL	69.634	69.634	141.848	141.848
SUPPORT INVESTMENT (millions $)				
Support Equipment	–	–	180.118	167.336
Spares	6.540	6.540	90.000	90.000
Software	–	–	1.029	1.029
Maintenance Training	–	–	–	–
Maintenance Manuals	0.389	0.927	1.369	1.666
Inventory Management	0.012	0.012	0.005	0.005
TOTAL	6.941	7.479	272.521	260.110
OPERATING AND SUPORT/YR (millions $/yr)				
On Equipment Maintenance	6.458	5.126	18.088	13.426
Off Equipment Maintenance	1.173	1.170	5.852	5.655
Maintenance Training	0.945	1.065	5.714	5.172
Aircrew	–	–	–	–
Aircrew Training	–	–	–	–
Spares	0.275	0.275	3.593	3.593
Depot Repair	3.093	3.093	15.233	15.233
Suport Equipment Maintenance	–	–	5.821	5.395
Maintenance Manual Maintenance	0.029	0.139	0.103	0.250
Software Support	–	–	0.434	0.434
Inventory Management	0.065	0.065	0.077	1.161
Disposal	–	–	0	0
TOTAL/YR	12.038	11.733	55.052	48.824

[6]landing gear

Table 20 – COST SUMMARY SUBSYSTEM LEVEL OPTIONS

	VHF Discrete	VHF Combined	SKE Standard	SKE Modified	Steel Brakes	Carbon Brakes
R&D COST	0	0		1.000	0	0.250
SYSTEM INVESTMENT (millions $)						
Hardware	3.181	4.024	18.686	17.599	4.241	6.474
Project Management	–	–	–	–	–	–
TOTAL	3.181	4.024	18.686	17.599	4.241	6.474
SUPPORT INVESTMENT (millions $)						
Support Equipment	–	–	–	–	–	–
Spares	2.250	0.863	11.625	9.533	3.163	3.243
Software	–	–	–	–	–	–
Maintenance Training			–	–		
Maintenance Manuals	0.038	0.037	0.163	0.151	0.064	0.064
Inventory Management	0.001	0.001	0.001	0.001	0.002	0.002
TOTAL	2.289	0.901	11.789	9.684	3.229	3.309
OPERATING AND SUPPORT/YR (millions $/yr)						
On Equipment Maintenance	0.329	0.006	0.455	0.294	4.137	4.047
Off Equipment Maintenance	0.288	0.005	0.378	0.189	0.651	0.650
Maintenance Training	0.196	0.003	0.195	0.114	0.696	0.681
Aircrew	–	–	–	–	–	–
Aircrew Training	–	–	–	–	–	–
Spares	0.232	0.082	0.321	0.254	0.153	0.153
Depot Repair	0.032	0.005	2.000	1.815	2.332	2.210
Support Equipment Maintenance	–	–	–	–	–	–
Maintenance Manual Maintenance	0.003	0.003	0.012	0.011	0.005	0.005
Software Support	–	–	–	–	–	–
Inventory Management	0.003	0.004	0.003	0.002	0.010	0.010
Disposal	–	–	–	–	–	–
TOTAL/YR	1.083	0.108	3.364	2.680	7.984	7.756

2.3.7 Human Resources, Logistics, and Cost Impact and High Drivers

The human resource, logistics, and cost impact or what might more appropriately be called an impact assessment is a summarization and presentation of the human resource, logistics, and cost data developed for any baseline and/or alternative under consideration. The previous sections in this report have described specific results of the various models and techniques that are included in CHRT. These data must be aggregated and presented in a convenient format for the decision maker. Tables 21 and 22 are examples of a format useful for presenting the data.

Table 21, for example, aggregates and presents data for two landing gear logistics options: the conventional versus task-oriented personnel, training, and technical manual approaches. Table 22 aggregates and presents data for a subsystem level option: a standard versus a modified SKE. These tables both have the same format and provide space for data on:

1. Research & Development (R&D) Costs
2. System Investment
3. Support Investment
4. Manpower Factors
5. Operations Risk
6. Schedule Risk
7. Operating and Support Costs
8. Technical Considerations

R&D costs, system investment, and support investment are obtained from the RMCM output. The Manpower Factors section of Tables 21 and 22 presents data on maintenance and operations manpower requirements. Maintenance manpower requirements are obtained as outputs of the R&M model, and the operations manpower requirements are derived from manual calculations. Operations Risk and Schedule Risk are important factors for a decision maker. Therefore space is provided for these data. Risk information, however, is not

Table 21 Impact Assessment—Landing Gear—Conventional vs. Task-Oriented Personnel, Training, and Technical Manual Approach

	Conventional	Task Oriented
R&D COST		
SYSTEM INVESTMENT (millions $)		
Hardware	69.634	69.634
Project Management	–	–
TOTAL	69.634	69 634
SUPPORT INVESTMENT (millions $)		
Support Equipment	–	–
Spares	6.540	6.540
Software	–	–
Maintenance Training	–	–
Maintenance Manuals	0.389	0.927
Inventory Management	0.012	0.012
TOTAL	6.941	7.479
MANPOWER FACTORS		
Maintenance Personnel Total	306	279
5 Level	216	138
3 Level	90	141
Maintenance Skills	14	14
Air Crew Total		
Officer		
Enlisted		
OPERATIONS RISK		
SCHEDULE RISK		

	Conventional	Task Oriented
OPERATING AND SUPPORT/YR (millions $/yr.)		
On Equipment Maintenance	6.458	5.126
Off Equipment Maintenance	1.173	1.170
Maintenance Training	0.945	1.065
Aircrew	–	–
Aircrew Training	–	–
Spares	0.275	0.275
Depot Repair	3.093	3.093
Support Equipment Maintenance	–	–
Maintenance Manual Maintenance	0.029	0.139
Software Support	–	–
Inventory Management	0.065	0.065
Disposal	–	–
TOTAL/YR	12.038	10.869
TECHNICAL CONSIDERATIONS		
Confidence		
Complexity		
Risk		
MMH/FH ($)	0.43	0.42
MMH/FH (F/L)	2.58	2.63
MFHBMA	4.35	4.55
Availability	0.5747	0.6019

Table 22 IMPACT ASSESSMENT–STATION KEEPING EQUIPMENT–STANDARD VS. MODIFIED

	Standard	Modified
R&D COST (million $)	–	1,000
SYSTEM INVESTMENT (million $)		
Hardware	18.636	17.599
Project Management	–	–
TOTAL	18.636	17.599
SUPPORT INVESTMENT (million $)		
Support Equipment	–	–
Spares	11.625	9.533
Software	–	–
Maintenance Training	–	–
Maintenance Materials	0.163	0.151
Inventory Management	0.001	0.001
TOTAL	11.789	9.684
MANPOWR FACTORS		
Maintenance Personnel Total	34	20
5 Level	23	13
3 Level	11	7
Maintenance Skills	3	3
Air Crew Total		
Officer		
Enlisted		
OPERATIONS RISK		
SCHEDULE RISK		

	Standard	Modified
OPERATING AND SUPPORT/YR (million $/yr)		
On Equipment Maintenance	0.456	0.294
Off Equipment Maintenance	0.378	0.189
Maintenance Training	0.195	0.114
Aircrew	–	–
Aircrew Training	–	–
Spares	0.321	0.254
Depot Repair	2.000	1.315
Support Equipment Maintenance	–	–
Maintenance Manual Maintenance	0.012	0.011
Software Support	–	–
Inventory Management	0.003	0.002
Disposal	–	–
TOTAL/YR	3.364	2.630
TECHNICAL CONSIDERATIONS		
Confidence		
Complexity		
Risk		
MMH/FH (S)	0.15	0.08
MMH/FH (F/L)	0.18	0.12
MFHBMA (Scheduled)	78.0	400.0
MFHBMA (Unscheduled)	28.3	40.3
MFHBMA (Combined)	19.7	36.6
Availability	0.8946	0.9303

developed within CHRT but must be obtained from other sources. Operating and Support Costs are obtained from the RMCM output. The technical considerations MMH/FH(S), MMH/FH(F/L), MFHBMA, and availability are obtained from the R&M model. The technical considerations of confidence, complexity, and risk, like operations and schedule risk, are not developed wihin CHRT. They are, however, also important factors fo a decision maker. Two factors not directly presented in the format which are assessed by CHRT are training course duration and technical manual content. These factors are presented indirectly, however, as the elements of support investment cost and operating and support costs. Obviously, CHRT human resource, logistics, and cost assessments should not be viewed in isolation; they must be considered in concert wih assessment of other factors, such as technical performance, operations requirements, and schedule.

Each impact analysis should be supplemented with a description of problem areas and recommendatioins. For example, the CHRT assessments could be reviewed for "high drivers," i.e., factors which excessively drive human resource, logistics, or cost. Excessive must be defined by the acquistiion or logistics manager so that assessment data may be screened with some established criteria to identify these "high drivers" (see AFHRL-79-28(I), reference 9 for a more detailed discussion and sample data). Once "high drivers" or other problem areas are identified, some recommendation regarding them should be made. Such recommendations, if accepted for consideration, would likely require another assessment to evaluate the impact of the recommendation.

2.3.8 Training and Technical Manual Products for Maintenance Personnel

In the full-scale development phase, the training and technical manual products as defined by CHRT consist of (a) the training/aiding matrix, (b) the intermediate products, and (c) a coordinated training program and technical manual set.

The training/aiding matrix would be accomplished typically in the early full-scale development phase. It is replaced in mid to late full-scale development by the intermediate products and the integrated task analysis. These intermediate products and the integrated task analysis

procedures were originally designed for technical manual development and are described in AFHRL-TR-73-43 (I, II) (references 7 and 8) and updated in AFHRL-TR-79-50 (reference 21). The integrated task analysis and intermediate products are used in CHRT, however, to prepare a coordinated training and technical manual program, tailored to a specific user population.

During this part of the CHRT demonstration, samples of all these products were prepared.

2.3.8.1 The Training/Aiding Matrix

The training/aiding matrix is developed from an automated analysis of task data inherent in the maintenance action networks. The matrix is useful in the conceptual, validation, and early full-scale development phases: (a) to identify critical information, (b) to assist in determination of special support requirements, such as media, presentation, or training devices, and (c) to better define and manage the training and technical manual programs.

Figure 5 depicts the training/aiding matrix developed for the projected AMST landing gear with task-oriented training and technical manuals supported on the flightline by 3-skill-level personnel. This matrix has been developed from the type data available in very early full-scale development before actual equipment is available for the task analysis. The degree of coverage for training and technical manuals appears as a ratio opposite the major subsystem or LRU code (refer to Table 1) and under the appropriate functional task category. The ratio depicts training coverage over technical manual coverage where 1 indicates light coverage, 2 indicates medium, and 3 indicates heavy. The functional task categories are labeled "flightline nontroubleshoot," "flightline troubleshoot," and "shop repair." This matrix may be used in early full-scale development to verify the scope of the training and technical manual development program and to reappraise any special requirements previously determined in the conceptual and validation phases.

EQUIPMENT	Flightline Nontroubleshoot	Flightline Troubleshoot	Shop Repair
GLG110	2/3	2/3	
GLG111			2/2
GLG112			2/2
GLG113			2/2
GLG114			2/2
GLG120	2/2	2/3	
GLG121		2/2	
GLG122			2/2
GLG123			2/2
GLG130	1/3	2/3	
GLG131			2/2
GLG140	3/1	3/3	
GLG141			2/2
GLG142			2/2
GLG143			2/2
GLG150	2/2	2/3	
GLG151			2/2
GLG152			2/2
GLG160	2/2	1/3	
GLG161			2/2
GLG162			2/2
GLG170	2/2	1/3	
GLG171			2/2
GLG172			2/2
GLG173			2/2
GLG174			2/2
GLG175			2/2
GLG176			2/2

Figure 5 AMST Landing gear MED phase - Task-oriented Training & T.O. - 3-skill level. Training/Aiding Matrix

2.3.8.2 Intermediate Products of the Integrated Task Analysis

An integrated task analysis was performed and a set of intermediate products was prepared during the full-scale development phase demonstration. The task analysis was limited to a single task on the C-141 landing gear, the removal and replacement of a main wheel brake. The task included jacking the aircraft, removal and replacement of the wheel, and removal and replacement of the brake. The task analysis was performed on a C-141 aircraft at Charleston AFB. The task was performed by Air Force maintenance personnel.

The following paragraphs will discuss the task analysis procedure as accomplished and will describe the resulting intermediate products. The intermediate products consist of the following:

1. Preliminary Task Identification Matrix (PTIM)
2. User Description
3. Technical Manual/Training Trade-Off Ground Rules
4. Task Analysis Work Sheets
5. Test Equipment and Tool Use Forms (TETUF).
6. Annotated Task Identification Matrix (ATIM).
7. Level-of-Detail Guide.

Simply stated, the integrated task analysis is the systematic study of the requirements of the task. It should result in a determination of what to train for and what behaviors and tasks a technical manual must support. Some behaviors will be supported only by training, some will be supported only by technical manuals, and some will receive support, in varying degrees, by both training and technical manuals.

The task analysis should be completed on actual hardware by hardware analysis, job observation, and interview. The hardware analysis should continually be updated through analysis of systems documentation, actual hardware, and interview with experts. Information on tasks involving the

hardware should be acquired via actual job observation. The user must always be kept in mind.

In this demonstration, the task analyzed was completed by a 5-level and a 3-level aircraft maintenance specialist. The task was observed and video taped. The personnel were interviewed during the task and afterward while observing the video playback.

2.3.8.2.1 PTIM

The first intermediate product of the integrated task analysis is the PTIM. In order to identify the tasks to be accomplished, there has to be a listing of the hardware components and their parts to the level at which the maintenance will be carried out. The results of this listing are provided in the PTIM. The PTIM lists system hardware item against the maintenance functions (adjust, align, etc.) which are carried out on the item and at which level (e.g., organizational (O) or intermediate (I)). Ideally, every piece of hardware that is associated with a task and every task that is to be carried out on a piece of equipment are identified. A sample PTIM is provided in Figure 6. This is one of 12 sheets prepared for the C-141, landing gear. Additional samples may be found in Volume II.

What comes next is a matter of preference. The AFHRL-TR-73-43 (I, II) (references 7 and 8) series describes a procedure that begins with a PTIM, then an ATIM, followed by a series of other documents. The procedure described must be tailored to the scope of the task. At this point, however, a description of the intended user of the technical manuals and training program should be prepared and verified. Additionally, work on the technical manual/training trade-off ground rules should be initiated.

2.3.8.2.2 User Description

Various types of user descriptions are discussed in AFHRL-TR-73-43 (I, II) (references 7 and 8). Initially, the Air Force would provide the technical manual developer with a preliminary user description, a statement of the type of maintenance personnel expected to be working on the system. The user description describes the personnel in

LANDING GEAR PRELIMINARY TASK IDENTIFICATION MATRIX (PTIM)

FOUND IN TROUBLESHOOTING	CODE					SYSTEM HARDWARE ITEM	DRC CODE	REFERENCE DESIGNATOR	ADJUST	ALIGN	CALIBRATE	CHECK OUT	TROUBLESHOOT	CLEAN	Disassemble/Assemble	INSPECT	LUBRICATE	OPERATE	REMOVE/REPLACE	REPAIR	SERVICE	NOTES
	1					Landing Gear System	GLG100	C-141														
	1	1				Main Gear	GLG110	C-141														
	1	1	1			Mechanical Components																
	1	1	1	1	1	STRUT			1	1		1	1	0	1	0	0	1	1	0	0	
	1	1	1	2		Piston Assembly						1	1	0	1	0	[illegible]	0	1	1	0	
	1	1	1	3		Cylinder Assembly						1	1		1	0	[illegible]	1	1	1	0	
	1	1	1	4		Torque Arm Lower						1			1		0		1			
	1	1	1	5		Torque Arm Upper						1			1		0		1			
	1	1	1	6		Brake Link AFT						1			1		[illegible]		1			
	1	1	1	7		Brake Link Forward						1			[illegible]		0		1			
	1	1	1	8		Drag Brace Forward						1			1		0		1			
	1	1	1	9		Drag Brace AFT						1			1		0		1			
	1	1	1	10		Unlock Assembly						1			[illegible]		0		1			
	1	1	1	11		Down Lock Assembly						1			1		0		1			
	1	1	1	12		Bogie Beam Assembly						1	1		1		0		1	1		
	1	1	1	13		Axle						1			1				1			
	1	1	1	14		Beam Positioner						1			1		0		1			
	1	1	1	15		Shaft Assembly MLG Support						1			1		0		1			

Figure 6 LANDING GEAR PTIM

terms of aptitudes, experience, and job-related skills and knowledges. At the same time, the Air Force would identify an existing group most analogous to the expected technical manual users. The technical manual developer would then assess this group to determine differences between the statement of characteristics listed in the preliminary user description and those of the analogous group. This assessment would eventually result in a modified user description, a more complete and realistic statement of the technical manual user.

Unfortunately, the AMST delay precluded full implementation of this procedure. Instead a description of the type of personnel who might have been assigned to the AMST was prepared and titled an "Estimated User Description." The technical manual sample was eventually prepared with this population in mind. The estimated user description is provided as follows.

ESTIMATED USER DESCRIPTION

The Estimated User Description (for the 431X2 career field) is that of person(s) being trained with task-oriented training procedures and supported by proceduralized technical manuals. The requirements are as follows:

1. Aptitude:
   A minimum of 50 obtained on the Mechanical composite, through the use of Armed Forced Vocational Aptitude Battery (ASVAB) scoring criteria for USAF personnel.

2. Reading Level:
   A reading level be obtained of more than 60 using the same scoring criteria.

3. Aptitude: Average (ASVAB)

4. Average Time in Service - 18 months

5. Prior Indirect Training - 3 months of Basic Military Training
   Prior Direct Training - Half of the personnel have the required AFSC and 30 days OJT. The other half have 8 weeks task-oriented training.

6. Prior Military Work Experience - Half have 2 years of C-130 experience. The other half have no military work experience.

Other information frequently included relates to their knowledge of the selection and use of test equipment; the selection and use of hand tools; and appropriate safety procedures.

2.3.8.2.3 Technical Manual/Training Trade-Off Ground Rules

The set of ground rules which direct the technical manual/training trade-off are also developed early in the integrated task analysis. These ground rules are similar for all systems but must be reviewed and modified for the particular weapon system and user of interest. These ground rules are initially used in developing the ATIM (discussed later) and in continuing the technical manual/traiing trade-off to lower levels. It is important to note that most tasks are covered in both manuals and training but the emphasis is different. For example, the need for test equipment and limits to be observed may be presented in a manual, but the use of test equipment is taught. Presented below is a simple set of ground rules which is particularly applicable to task-oriented training and proceduralized manuals. This set of ground rules was used in the present demonstration.

Put into Technical Manuals

1. Behavioral sequences that are complex and long and which would put a burden on memory.

2. Behavioral sequences which would require extremely lengthy training/practice periods to produce sufficiently reliable performance.

3. Tasks that utilize reference information such as tables, graphs, flow charts and schematics, tolerances, etc.

4. Tasks that are aided by the presence of illustrations.

5. Task that involve complex discriminations or where similarity of cues cause confusion.

6. Tasks that are performed under stressful conditions that might degrade performance - except time stress.

7. Infrequently performed tasks.

8. Tasks where the probabilty of error is high and errors are costly.

9. Tasks with branching step structures.

10. Where low skill level personnel are used.

11. Where turnover is high.

12. Where procedures change from time to time.

Put into Training:

1. Tasks that are not easily described in book form.

2. Tasks that are not easily learned on the job (unless they can be put into tech manuals).

3. Tasks that need a great deal of practice for acceptable proficiency.

4. Tasks where there is little room for error and the errors are costly.

5. Tasks which are performed frequently on the job.

6. Tasks requiring high speed - where the rate stimulus inputs are high and response outputs are high.

7. Tasks that are performed under stress - especially time stress.

8. Where environmental constraints interfere with or prohibit use of aids.

9. Tasks performed by a large proportion of individuals in a given specialty.

2.3.8.2.4 Task Analysis Worksheets

Based on the demonstration experience the Task Analysis Worksheets are the second major step and the key intermediate products. The initial base for these sheets is the PTIM which provides hardware definition. The task identification and description information presented on these data sheets is completed bit by bit as the analysis proceeds. The purpose of these worksheets is

1. To identify and verify hardware elements and task steps.

2. To describe the cue and accompanying responses for each step.

3. To ascertain the sensory, motor, cognitive demands on the technician.

4. To determine essentially how the technician knows what to do, when to do it, how to do it, and what feedback is available to indicate it is done correctly.

5. To list tools and equipment used.

6. To evaluate safety hazards and environmental factors.

Enough detail is first acquired to identify the cues and responses required to accomplish the task. Detailing to this level, however, requires an intensive examination of the equipment and tasks. Therefore, the completion of this information will come about during the interview and job observation activity. It is difficult to complete the several documents called for in AFHRL-TR-73-43 (I, II) (references 7 and 8) until this level of detail of task identification and description has been reached; otherwise, the information allocation to training and/or technical manual would be quite arbitrary.

The task analysis worksheets prepared for the C-141 landing gear are provided in Volume II. A sample is shown in Figure 7. This worksheet provides several columns for data. The first two columns, "task number" and "task description," provide the space to identify the hardware elements and task steps, and to describe the cue and response for each step. These two columns along with a third column, "notes and cautions," also provide space for the documentation of

TASK ANALYSIS WORK SHEET

Task #	Task Description	Notes & Cautions	Tools & Equipment	Training & JPA Implications
A6.	Set parking brakes			
a)	Depress upper portion of rudder pedals			
b)	Pull out parking brake handle			
c)	Release rudder pedals			
7.	Deflate Tire	A-7 Caution: since tires are inflated to 200 psi, use extreme care when	valve core tool	A-7 Trg. Use of valve core tool How to deflate tire slowly Safety precautions
a)	Remove valve cover (28)			
b)	Using valve core tool, deflate tire until no further air comes out			
c)	When tire is deflated, using valve core tool, remove valve core (27)			
8.	Remove:	Note: rings & seals should be inspected for wear or defects	screwdriver or cotter pin remover	A-8 Trg. To facilitate discrimination, show defective or work parts.
a)	Snapring (23)			
b)	Hubcap (5)			
c)	Grease retainer ring (9)			
d)	Felt grease seal (10)	Note: place removed parts in hubcap in order they were removed		
9.	Disconnect anti-skid device			
a)	Using wire snippers, cut and remove safety wire	Note: if screws are especially difficult to loosen, use vice grips. If screw heads are badly chewed up, they should be replaced		
b)	Using screwdriver, remove three screws from skid detector			
c)	Place in hubcap for safekeeping			
d)	Rotate skid detector 1/2 turn and slide it inside axle (22)			
		Note: before doing step #10 check wheel for visible cracks or defects		

Figure 7 TASK ANALYSIS WORKSHEET SAMPLE

specific sensory, motor, or cognitive demands on the technician. The "notes and caution" column also provides space to document other task information, to direct the use of alternative tools and to note safety hazards and environmental factors. The tools and equipment required are covered in a fourth column labeled "tools and equipment." The fifth column, "training and JPA[7] implications," allows the documentation of objectives or functions that should receive special emphasis during training and/or in the technical manual.

2.3.8.2.5 TETUF

As the task analysis worksheets are completed, the TETUFs are also completed. A sample tool use form for the brake task is shown in Figure 8. A complete sample set is in Volume II. The TETUF provides columns for documenting the functions of the test equipment or tools, and for identifying the information to be allocated to technical manuals or training. This latter determination is made using the technical manual/training trade-off ground rules previously described.

2.3.8.2.6 ATIM

The detailed task data available from the completed worksheets and the completed technical manual/training trade-off ground rules facilitate the completion of the ATIM. The technical manual/training trade-off ground rules established for the desired personnel, training, and technical manual approach assure that appropriate allocations in task information coverage to training and the technical manual are made. The ATIM developed for the brake

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[7] JPA - job performance aid, used here synonymously with technical manual.

TEST EQUIPMENT AND TOOL USE FORM

Torque Wrench Equipment Nomenclature Date __________

PN 7227089-10 Equipment Number Analyst __________

Functions	JPA Training Trade-Off	
	Information to be included in JPA	Information to be given in training
1. Calibrated to 960 inch-pounds - to torque axle nut 2. Calibrated to 480 inch-pounds - to torque axle nut after checking lock ring 3. Calibrated to 600 inch-pounds (rectangular head) to check lock ring	1. Steps in tightening nut and ring 2. Steps in aligning lock ring holes	1. How to use torque wrench 2. Importance of keeping lock ring in place while tightening nut 3. Alignment of lock ring holes

Figure 8

LANDING GEAR DETAILED ANNOTATED TASK IDENTIFICATION MATRIX (ATIM)

(TASK – REMOVE AND REPLACE MAIN LANDING GEAR BRAKE)

03/79

H = Hand
B = Bench
J = Joint

CODE					SYSTEM HARDWARE ITEM	DRC CODE	REFERENCE DESIGNATOR	1 ADJUST	2 ALIGN	3 CALIBRATE	4 CHECK OUT	5 TROUBLESHOOT	6 CLEAN	7 DISASSEMBLE/ASSEMBLE	8 INSPECT	9 LUBRICATE	10 OPERATE	11 REMOVE/REPLACE	12 REPAIR	13 SERVICE	NOTES
1					Landing Gear System																
1	1				Main Landing Gear																
1	1	1			Mechanical Parts																
1	1	1	32		Lever Rod Assembly		37							H							
1	1	1	32	1	Cotter Pin		36											H			
1	1	1	32	2	Nut		35							H							
1	1	1	32	3	Washer		34							H							
1	1	1	32	4	Washer		30							H							
1	1	1	33		Torque Link Assembly		31							H							
1	1	1	33	1	Bar Washer		32											H			
1	1	1	33	2	Nut		33							H							
1	1	1	33	3	Bolt		30							H							
1	3				Brakes/Anti Skid		20 - 8														
1	3	1			Skid Detector		6							B	B						
1	3	2			Brakes		20														
1	3	2	1		Rotor Discs				H					J							
1	3	2	2		Spacer (Outer)		19						B	B	J						
1	3	2	3		Spacer (Inner)		21						B	B	J						

Figure 9

removal task is provided in Volume II. A sample is shown in Figure 9. Basically, this form provides a matrix upon which the technical manual/training allocation can be documented. The columns of major interest are labeled "system hardware item" and "maintenance function." Sub-columns under "maintenance function" identify specific functions such as adjust, align, etc. The fact that a maintenance function is performed on a system hardware item is determined during the task analysis. This fact is also documented on the ATIM along with an annotation which indicates where the allocation of information will be emphasized. The possible choices are training (H), technical manual (B), or jointly (J). The notations H and B have traditionally stood for head and book, respectively. Therefore, an H at the juncture of the system hardware item, leveler rod assembly, and the maintenance function, disassemble/assemble, indicates that this task will be emphasized in training, rather than in the technical manual.

2.3.8.2.7 Level-of-Detail Guide

The level-of-detail guide is established in parallel with the foregoing activity. The completed ATIM, level-of-detail guide and test equipment and tool use forms provide the final intermediate product package. The information provided in this intermediate product package may be supplemented with several other intermediate products suggested by AFHRL-TR- 73-43 (I, II) (references 7 and 8). The level-of-detail guide developed for the landing gear task is provided in Volume II.

2.3.8.3 The Coordinated Training Program and Technical Manual Set

A final step in CHRT as a product development methodology is the preparation of the coordinated training program and technical manual set using the intermediate products of the integrated task analysis. During this demonstration of CHRT in the full-scale development phase, the intermediate products of the intergrated task analysis prepared on the C-141 main wheel brake removal task were used to develop a sample training plan and technical manual set. The samples are task-oriented in nature and were developed to support the performance of flightline tasks by personnel with 3-

level skills. This coordinated training plan and technical manual sample set have been prepared to implement the task-orient personnel, training, and technical manual approch reflected in the human resource, logistics, and cost assessments discussed earlier in this report.

The training plan addresses the 431x2 AFSC, aircraft maintenance specialist. The training plan sample was developed using ISD procedures and supports a monitored self-instructional approach. It is oriented toward teaching the use of tools and performance of the tasks directly related to the brake change. Emphasis is placed on the more complex tasks and safety. An example of a performance objective contained in the training plan and developed during this demonstration is provided in Figure 10.

The technical manual addresses the brake removal and replacement task and all the subtasks which must be accomplished. A sample page is provided in Figure 11. Emphasis is on clearly defined procedures which can be used efficiently by both experience and inexperienced personnel. The technical manual sample was prepared in job guide format with information presented in a series of major steps and sub-steps. The major steps are directive in nature and are all that is really needed by an experienced individual. The sub-steps are primarily informative in nature and are meant as an aid to the less experienced technician. One fold-out illustration is included in the sample and provided here as Figure 11. This illustratioan was developed to accurately and realistically depict the hardware that the technician would handle. The fidelity of the illustration is very important in identifying the various hardware elements.

The complete sample training plan and technical manual set are enclosed in Volume II. At the present time, the task for which these products were developed is covered by T.O. 1C-141A-24-JG-6. The reader might examine that technical manual for comparison purposes.

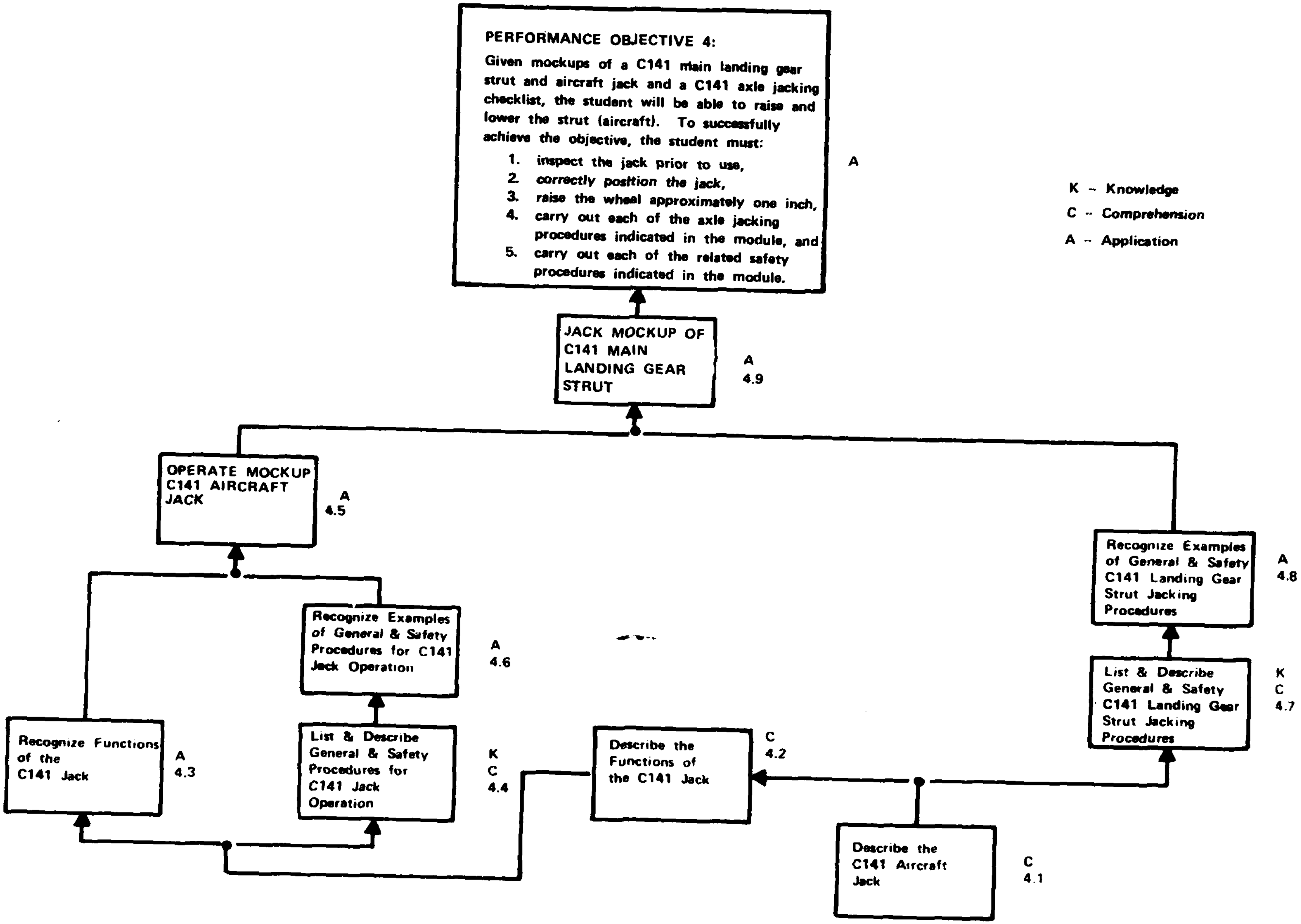

Figure 10 PERFORMANCE OBJECTIVE SAMPLE

REMOVE WHEEL AND TIRE

NOTE: If there is not enough room between the aircraft and axle to remove the wheel, inflate both landing gear struts. (Refer to T.O. 1C-141A-2-2JG-4)

1. Make sure that the parking brakes are off.

2. Remove forward and aft chocks.

3. Disconnect leveler rod (37).

    a. Remove cotter pin (36).

    b. Remove nut (35).

    c. Remove outer washer (34).

    d. Free leveler rod by pulling it off of bolt.

    e. Leave inner washer (38) in bolt and put outer washer (34) and nut (35) onto bolt for safekeeping.

    f. Tie leveler rod to forward torque arm so it will not dangle or be damaged.

4. Jack axle until tire clears ground. (Refer to T.O. 1C-141A-2-2JG-4).

5. Set parking brake.

    a. Depress top part of rudder pedals (40).

    b. Pull out parking brake handle (39).

    c. Release rudder pedals (40).

    NOTE: If parking brake handle will not set in the out position, check to make sure that there is enough hydraulic pressure (refer to T.O.   )

Figure 11 - Technical manual sample.

6. Deflate tire.

   a. Remove air valve cover.

   b. Use valve core tool to deflate tire until all air is out.

   c. Use valve core tool to remove valve core.

7. Remove outer wheel hardware.

   a. Remove snapring (23).

   b. Remove hubcap (5).

   c. Remove grease retainer ring (9).

   d. Remove felt grease seal (10).

Figure 11 Technical manual sample (continued).

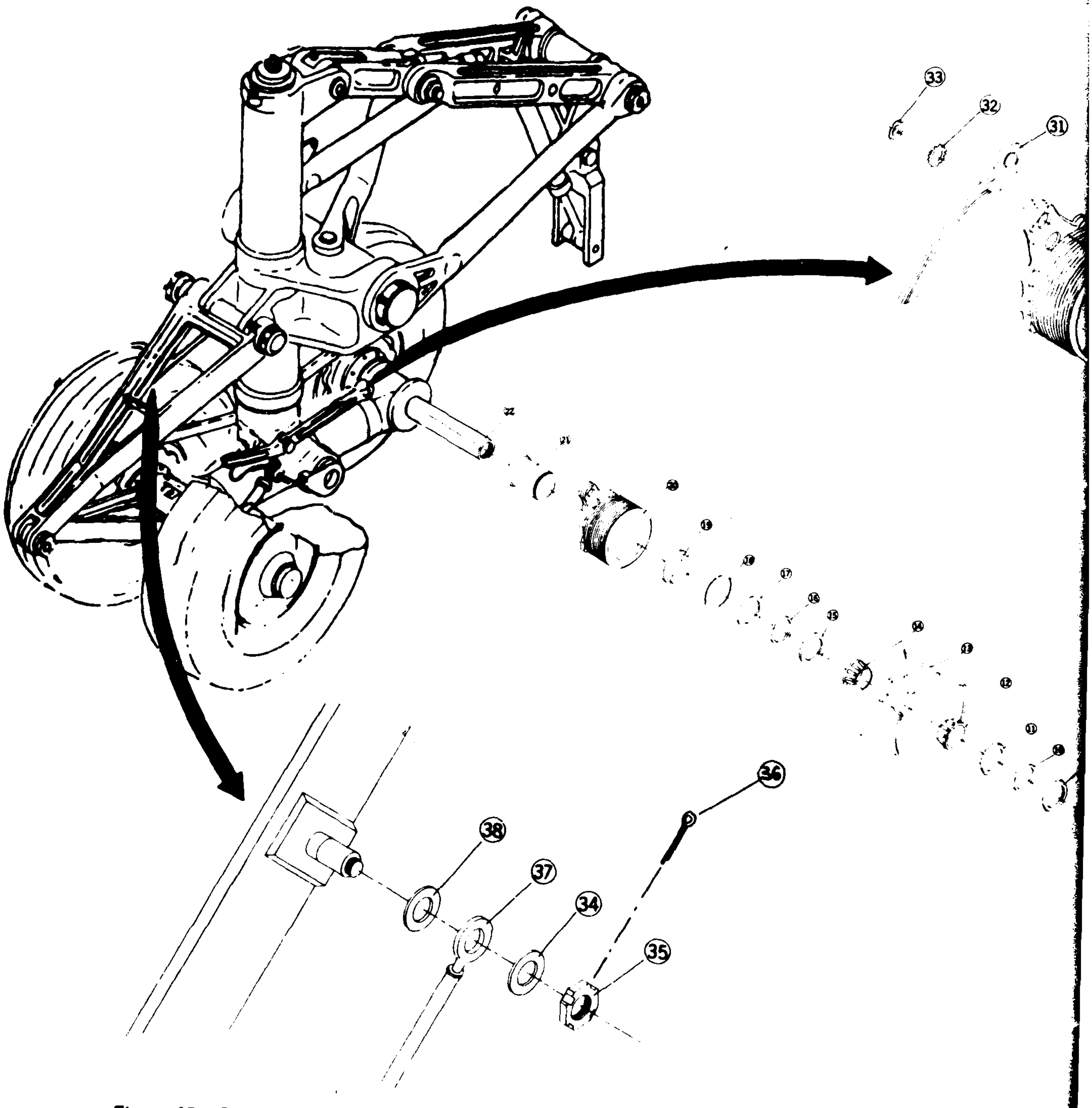

Figure 12 C-141 WHEEL AND BRAKE ASSEMBLY

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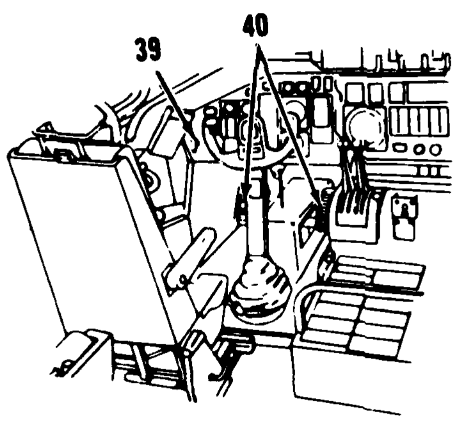

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III. CONCLUSIONS

The results of the full-scale development (MED) phase demonstration support the conclusions from the conceptual and validation (prototype) phases that selected human resource, logistics, and cost data (a) may be developed on a weapon system through a logical, rational, and repeatable process, and (b) may be obtained at succeedingly more detailed levels of the system design and the support plan as acquisition proceeds. The full-scale development phase results confirmed again that an integrated task analysis performed on actual equipment is feasible and can lead to a coordinated training and technical manual set which implement the support plan reflected in the human resource, logistics, and cost data.

The following paragraphs will provide specific conclusions drawn from this demonstration. These conclusions will address the applicability of CHRT in weapon system acquistion, and the validity of the results obtained during the demonstration. Finally, some related demonstration results will be pointed out and areas for future work will be identified.

3.1 APPLICABILITY OF THE METHODOLOGY

This report marks the completion of the demonstration of CHRT in the full-scale development phase of acquisition. It also marks the end of the total demonstration effort which covered the conceptual and validation phase of acquisition as well. It is appropriate, therefore, to incorporate in this report conclusions regarding the applicability of CHRT in all phases of the acquisition process. Each conclusion is supplemented with supporting statements drawn from the demonstration experience.

A. CHRT and the CDB may be initiated as early as the conceptual phase and applied with continuity throughout acquisition.

   1. CHRT and the CDB were initiated on an aircraft avionics and landing gear systems using conceptual phase data. Human resource, logistics, and cost assessments were made.

76 Blank

2. The CDB was sequentially upated with both validation phase and full-scale development phase data. CHRT was applied at several levels of detail within the avionics and landing gear systems under consideration. Previous human resource, logistics, and cost assessments were updated, and new and more detailed assessments were made.

B. Application of CHRT as both an assessment and product development methodology is feasible.

1. The actual equipment data required for the continued evolution of a data base adequate to support the more detailed system design and support plan assessments are available or can be obtained.

2. The methodology is sensitive to system design and support plan options at the subsystem, LRU, and SRU levels.

3. The impact of an integrated personnel, training, and technical manual approach may be directly reflected in the maintenance networks and in the human resource, logistics, and cost assessments.

4. The integrated task analysis supports the development of a coordinated training program and technical manual set.

C. CHRT is a useful management tool during weapon system development.

1. The human resource, logistics, and cost assessments developed through CHRT provide the system manager information at the level of detail needed to influence the design baseline and support plans.

2. The assessments and training/aiding matrix derived during the early sull-scale development phase can assist in defining the content and scope of the personnel, training, and technical manual program to be implemented during the middle to late full-scale development phase.

3. The intermediate products of the integrated task analysis provide task information for the training and technical manual products. These intermediate

products, which are procured during the middle full-scale development phase as the first step in a two-step training program/technical manual development process, may be used also to define and negotiate the second step, development of the actual training and technical manual products.

D. A single CDB can support throughout acquisition the application of the five technologies integrated under CHRT. This eliminates the need for multiple data bases.

1. A single CDB was initially established for this demonstration using conceptual phase data. The CDB was then updated and maintained as necesssary to effectively support CHRT application as both an assessment and product development methodology.

2. With very few exceptions, the data groups contained in the CDB service one or more technologies.

3. The data required for the CDB are available from historical, estimated, or actual data sources as appropriate during each acquisition phase.

3.2 VALIDITY OF RESULTS

The validity of the design and support plan assessments made using the CHRT methodology remains a central issue that must be addressed. This is a central issue to all pedictive methodologies used in system acquisition. In this demonstration of CHRT, there is no external evidence regarding the validity of the assessments made. Confidence in the predicted manpower, reliability, maintainability technical manual, training, and cost requirements is dependent upon confidence in the logic of the procedure, the reasonableness of the assumptions, and the relevance of the input data. Even when external evidence is available, it must be reviewed very carefully to assure it reflects the same parameters and conditions reflected in the predicted data.

Clearly, judgement must be used in applying the results of CHRT analyses to engineering and management decision-making during system acquisition or retrofit. The judgement must be based both on a knowledge of the methodology and an

understanding of weapon system acquisition and logistics. The greatest confidence can be placed in the methodology when it is used to assess the relative merits of alternatives at the system and subsystem levels. The least confidence should be placed in CHRT assessments as absolute values. This conclusion, however, is true of any predictive methodology. New investigations are needed to address this central issue of the validity of predicted requirements. However, CHRT, even in its present form, is a valuable tool for the weapon system or logistics engineer and manager. CHRT provides a systematic, quantitative, and traceable procedure for addressing human resource, logistics, and ownership cost issues involved in a system acquisition program. It also provides another valuable characteristic, continuity of procedure throughout acquisition. CHRT, as a predictive or assessment oriented methodology, therefore, represents a significant advance over current practices.

The validity of the training and technical manual products prepared using the CHRT methodology is another subject that must be considered. In this case, however, there are three responses regarding validity depending on the particular product being evaluated.

First, the validity of those products, such as the personnel, training, and technical manual section of an ILSP and the training/aiding matrix which were developed using design assessment data, must be subjected to the same judgement as the assessments themselves. The products, like the assessments, are only as good as the input data and the techniques used to prepare them. The assessments, however, and the products mentioned are the result of a systematic, quantitative, and traceable procedure which can be questioned and iterated.

Second, the validity of the intermediate products of the integrated task analysis are less open to question. These products reflect the allocation of task information to training and technical manuals. When properly prepared, they form the basis for a coordinated training and technical manual program. The validity of the task analysis technique has long been established. The central issue here is not the validity of the technique or of the intermediate products. It is the cost of terms of time and money, scarce commodities in any system development or production program. The return on an investment in task analysis and selected intermediate products comes during the deployment and operations phase and is difficult to estimate.

Third, a coordinated training program and technical manual set is logically compelling, but to date has not been adequately demonstrated and validated. The actual implementation of this concept is very slow in coming. Traditionally, training and technical manuals have been the province of different agencies and remain so today. As a result, training and technical manuals are rarely developed from the same task analysis or as a coordinated set. The question here, then, is not validity, but feasibility. The approach is feasible but only with extraordinary cooperation. The coordianted training program and technical manual set is a prime example of a theoretically correct approach which is difficult to implement in the often disjointed and uncoordinated "real world."

3.3 RELATED DEMONSTRATION RESULTS

Significant effort was expended during the demonstration phase of this study to develop, improve, and integrate the analytic models and procedures which make up the CHRT methodology and which satisfy the data requirements. Several areas are worthy of mention here. The first two are covered in detail in the final report on the methodology. The last is discussed in Volume II of this report. These areas are:

1. Intermodel compatibility among LCOM, the expected value model and the R&M model.

2. The early prediciton of training/aiding requirements.

3. The application of LCOM to support equipment maintenance action networks.

3.4 AREAS FOR FUTURE WORK

CHRT and the CDB presently have very definite potential for application as management tools in the wepaon system acquisition process. Their potential may be increased, however, if improvements are initiated to enhance the quality of the present methodology and to extend the

methodology to additional human resource, logistics, and cost factors. Some general reccmmendations are as follows:

1. A technique to assess aircraft system software maintenance reuqirements to complement the existing hardware assessment capability.

2. A cost model supplement for LCOM, to allow LCOM to drive the RMCM.

3. Improved techniques tc assess the impact of design approach and support plans on specialty, technical, and on-the-job training requirements.

4. Enhancement of tahe RMCM to address the phase-in and phase-out of a system during the life cycle.

5. Extension of the CHRT to quantify spares requirements and other areas of technical data such as engineering drawings and provisioning information.

6. Improved techniques to allow CHRT to assess SE operation and SE maintenance manpower requirements.

7. A test and evaluation of CHRT and CDB in a realistic weapon system acquisition environment.

8. Extension of CHRT and CDB methodologies for application to ground electronic systems and to missile and space systems.

ABBREVIATIONS AND ACRONYMS

2 MFD	two-member flight deck
A	availability
A/C	aircraft
AFHRL	Air Force Human Resources Laboratory
AFM	Air Force Manual
AFSC	Air Force Specialty Code
AFTEC	Air Force Test and Evaluation Center
AM	amplitude modulation
AMST	Advanced Medium STOL Tranport
ASD	Aeronautical Systems Division
ATIM	annotated task identification matrix
CDB	consolidated data base
CND	cannot duplicate
CHRT	coordinated human resource technology
CONUS	continental United States
CRT	cathode ray tube
DAIS	digital avionics information system
DF	direction finding
DOD	Department of Defense
DODT	design option decision tree
DSARC	Defense Systems Acquisition Review Council
F/L	flightline
FM	frequency modulation
HF	high frequency
HOL	high order language
HRDT	human resource in design trade-offs
HUD	heads-up display
IFF	interrogator friend or foe
ILS	integrated logistics support
ILS	instrument landing system
ILSP	integrated logistics support plan
INS	inertial navigation system
ISD	instructional system development
JGD	job guide development
LCC	life cycle cost
LCOM	logistics composite model
LF	low frequency
LRU	line replaceable unit
LSA	logistics support analysis
LSAR	logistics support analysis record
M	maintainability
MED	minimum engineering development
MFHBMA	mean flight hours between maintenance actions
MMH/FH	maintenance man hours/flight hour

ABBREVIATIONS AND ACRONYMS (continued)

MMM	maintenance manpower modeling
MTTR	mean time to repair
NOA	not operationally available
NRTS	not repairable this station
NTS	non-troubleshooting
O&S	operations and support
PTIM	preliminary task identification matrix
QPA	quantity per aircraft
R	reliability
RFP	request for proposal
RIW	reliability improvment warranty
RMCM	reliability, maintainability, cost model
ROC	required operational capability
SE	support equipment
SKE	station-keeping equipment
SOC	system ownership cost
SRU	shop replaceable unit
STOL	short field takeoff and landing
TACAN	tactical air navigation system
TETUF	test equipment tool useform
TS	troubleshoot
UE	unit equipped
UHF	ultra high frequency
VHF	very high frequency
VOR	visual omni range
WUC	work unit code

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APPENDIX A
MAINTENANCE ACTION NETWORKS

The concept of the maintenance action network as a means of modeling the maintenance system is critical to the application of the CHRT. To ensure a basic understanding, a very brief description of the maintenance action network as used with the R&M model is provided in the following paragraphs. A more complete description is included in AFHRL-TR-78-2(I) (reference 1).

A maintenance action netawork is depicted in Figure A-1. This network represents the possible unscheduled maintenance actions which may occur within a subsystem of an aircraft major system, for example, the radar subsystem of the avionics system. Maintenance actions are performed either at the organizational (flightline) or intermediate (shop) level. Depot level maintenance is not depicted. With minor modification this format may also be used to represent scheduled maintenance.

Each node in the network representation indicates the beginning and/or end of a specific event such as subsystem failure, or troubleshoot action. As used in CHRT, each event is annotated with certain information. With the exception of subsystem failure, each event is annotated to indicate (a) the probability that the event will occur, (b) the time to complete the event, (c) the maintenance personnel characteristics (skills, levels, and quantity) to support the event, and (d) the support equipment (type and quantity) required to support the event. Subsystem failure is annotated only with probability of failure occurrence.

These networks are then translated to computer cards in a format compatible with both the R&M model and RMCM. The R&M model operates on these networks and provides average values for both maintenance manpower requirements and mean time to repair at the subsystem level for the flightline and at the LRU level for shop. The model also computes availability for both the major system and subsystem levels. The RMCM operates on these data similarly but uses the results internally for cost computations.

The data used to annotate these networks in the early acquisition phases are developed from an analysis of historical data on comparable equipment. This analysis is partially judgemental and must consider the source of the

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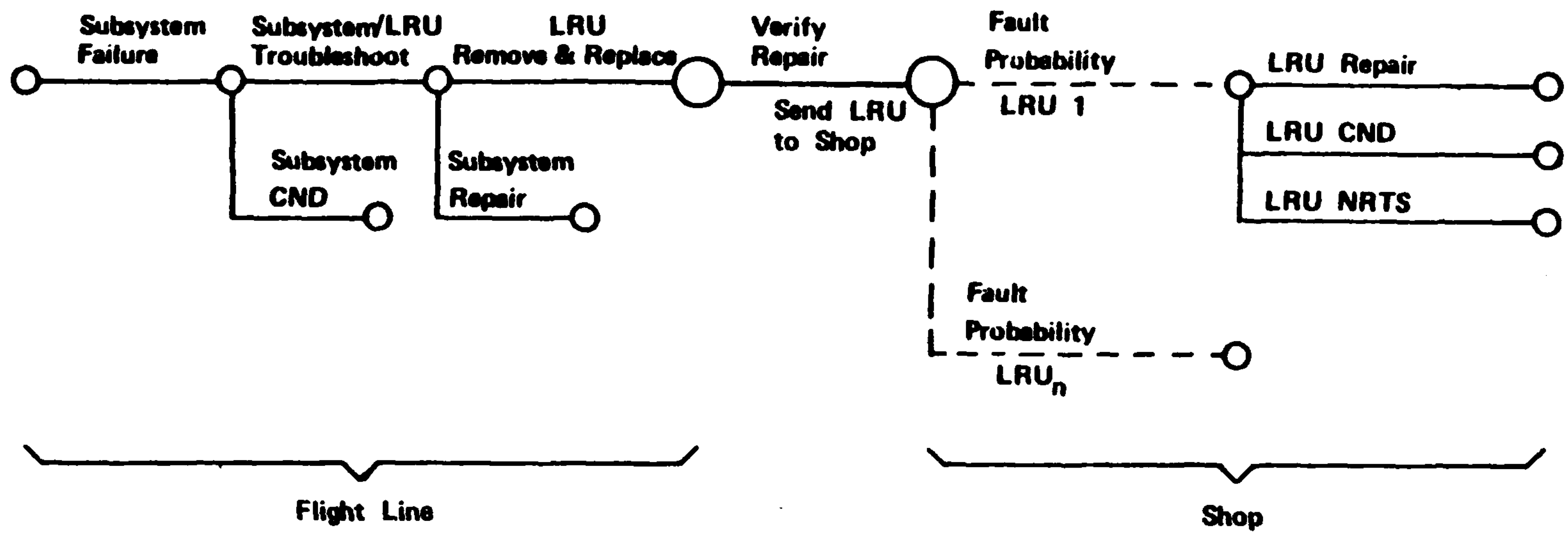

LRU - line replaceable unit
CND - cannot duplicate
NRTS - not repairable this station

Figure A-1 Generalized maintenance action network.

historical data and the intended application of the proposed system. Historical data are gradually replaced with actual subsystem data as the subsystem hardware is built and use data are collected. The networks, therefore, grow from an estimated to an actual model of the maintenance system.